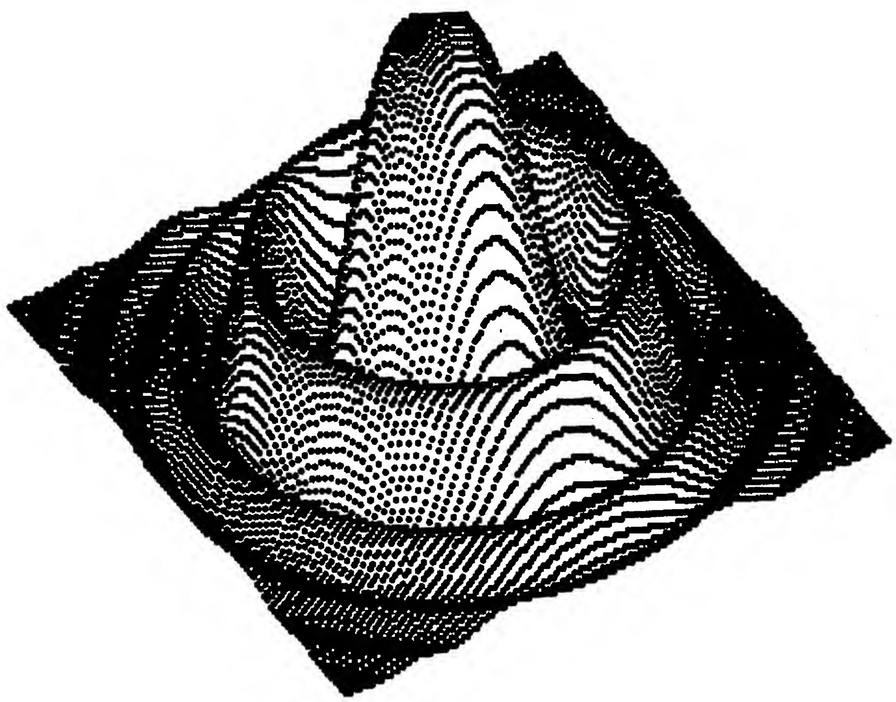
MICROANGELO USER'S MANUAL



RELEASE 1.0

SCION Corporation

June 1980

Warranty

SCION Corporation certifies that each computer system will be free from defective materials and workmanship for ninety (90) days from date of shipment to the original customer. The only exceptions will be the video monitor and keyboard which will reflect their manufacturers' warranty. (Monitor - 1 year, Keyboard - 1 year).

SCION Corporation agrees to correct any of the above defects when the system is returned to the factory prepaid. Written authorization must be obtained and confirmed in writing by the Customer Service Department before returning the equipment to the factory.

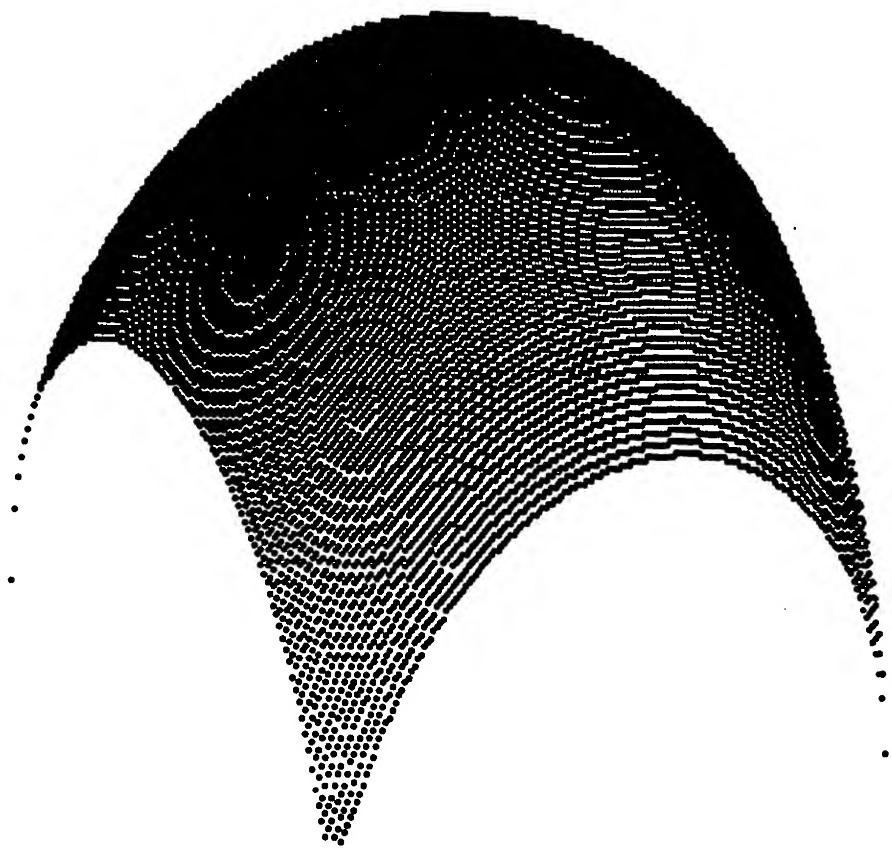
Under this warranty, SCION Corporation will, at the request of the customer, provide the necessary components required by the customer to correct the equipment in the field. The components will be shipped, prepaid, on a billing memo which will be cancelled upon receipt of the defective components at the factory. When ordering components for repair or replacement, the model number and serial number must be included on the customer request.

This warranty is invalid if the system is subject to mis-use, neglect, accident, improper installation or application, alteration or negligence in use, storage, transportation or handling and where the serial number has been removed, defaced or changed.

FOREWORD

With MicroAngelo™, SCION Corporation brings its most flexible and sophisticated video product to the market. To our knowledge it is the only "no-load" high resolution refreshed raster scan graphics system available. For the user, no-load says two things: First it means freedom from the woes of standard memory mapping video; MicroAngelo™ takes none of your host system address space. Second, it means performance approaching graphic systems ten times the price. The time-multiplexed Z80 microprocessor resident on MicroAngelo™ can be run at 4 or 5 Mhz and achieves vector plotting at speeds exceeding 10,000 pixels per second.

As a demonstration of some its capability, MicroAngelo™ was used to generate all of the graphic and non-standard characters in this manual. Printout was accomplished by a Qume Sprint5 hardcopy device operating in graphics mode with a resolution of 1/60 inch.



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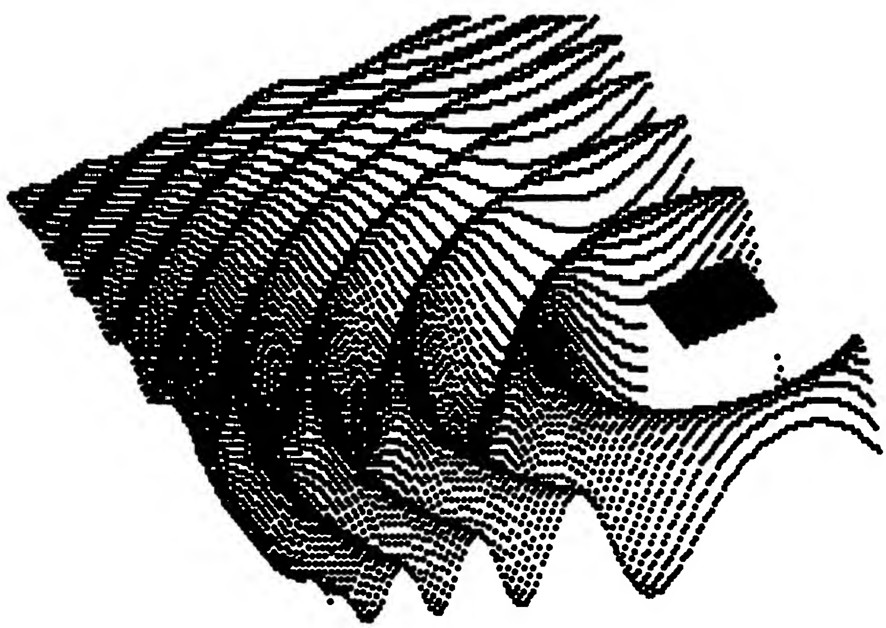

The MicroAngelo (TM) Graphics System User's Manual

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1. General Information

MicroAngelo (TM) is an intelligent high resolution refreshed raster scan graphics display system capable of drawing character and graphic images at high speed on a standard television monitor. Completely contained on a single S100 bus card, MicroAngelo is an independent Z80A-based computer with its own 32K byte display memory and 4K resident operating system, Screenware Pak I (TM). By talking in concise high level commands over a simple interface, your host computer directs MicroAngelo in generating graphics and text displays and in controlling the light pen interface. Because of its self-reliant architecture, MicroAngelo places no computing load or memory space demand on your computer. This means that, after giving directions to MicroAngelo, your CPU can continue with its own computing as MicroAngelo concurrently carries out those directions using its own separate memory and CPU. The results are a more responsive and convenient graphics/text display system than ever before possible with traditional graphics board designs.

1.1. Brief System Overview

The MicroAngelo hardware resides on a single S100 bus board. This board contains all the electronics and software for generating a 512 dot wide, 480 dot high, black and white display for a high-resolution TV monitor (10 mhz bandwidth or better). Since the board includes a Z80A microprocessor, complete with its own RAM (32K bytes), EPROM (up to 8K bytes), and TV display circuitry, MicroAngelo is actually an independent, single card computer which, when inserted into your computer, appears to your system as two parallel ports. This architecture makes it possible for your computer to direct MicroAngelo via simple, powerful high-level graphics commands sent over the two parallel ports, then proceed with its own computations while MicroAngelo carries out the display generation in parallel. Because of this simple and fast two-port interface, MicroAngelo is easy to integrate and does not require <u>any</u> of your system's valuable address space.

The MicroAngelo software, Screenware Pak I, has been designed so that the system can be used either as your main console output display, or as a separate graphics display processor, or both. Logically, Screenware Pak I consists of two largely independent software subsystems called ALPHA and GRAPHICS. ALPHA emulates a "dumb terminal" interface, while GRAPHICS supports all the graphics primitives. To get on the air with MicroAngelo as your main output device, you need only implement the simple interface to ALPHA shown below.

1.2. Quick Integration Steps

(Unless otherwise indicated, all memory addresses and operation codes throughout the manual are in hexidecimal notation.)

To interface MicroAngelo to your computer as the main output device, do the following three things:

1. Decide whether or not the MicroAngelo parallel ports, mapped from F0-FF, are compatible with your system. If your system currently uses any port in this range, you may have to alter the Port Address Jumpers to some other 16-port boundary. This procedure is described in the section entitled "Changing the Port Addresses".

2. Install the following interface code as your system's main ("console") output routine. This code will send the byte in the A register to MicroAngelo's ALPHA component, and appear to your operating system to be a "dumb terminal" interface:

```
ttyout   push  psw        save the output byte
tyo1     in    0F1H       read the Control Port
         ani   1          test buffer-full bit
         jnz   tyo1       wait until not full
         pop   psw        restore the output byte
         out   0F0H       send it to the Data Port
         ret              return
```

   If you have changed the port addressing as the result of Step 1 above, replace the references to output ports F0 and F1 in this code to the appropriate new values. The software interface to MicroAngelo is described in more detail in the section entitled "Screenware Pak I - The

Onboard Software".

3. Connect MicroAngelo to a TV monitor, as described in the section entitled "Basic System Integration".

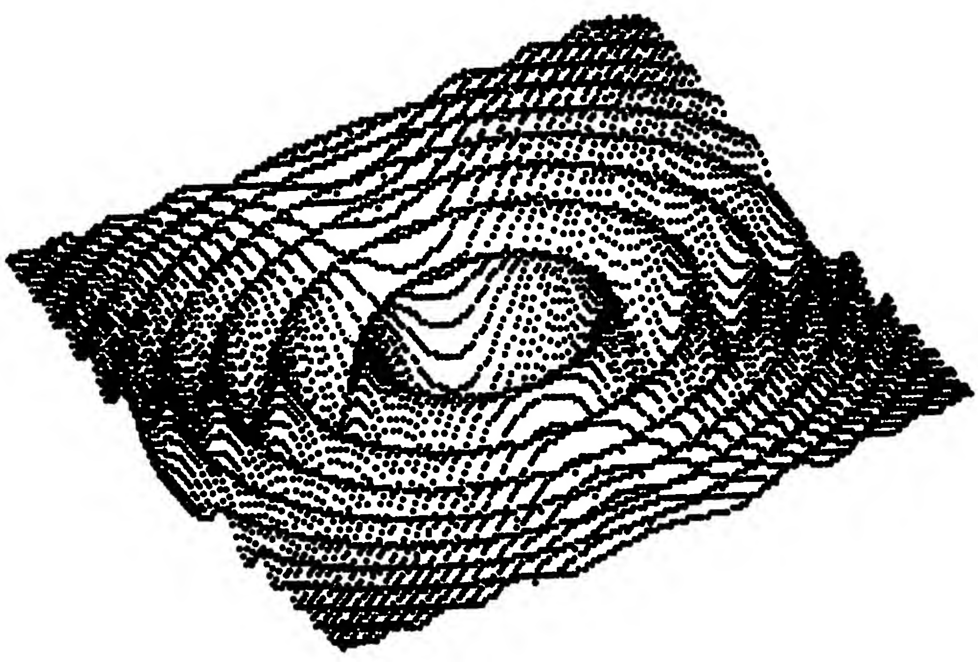
At power-up time, MicroAngelo will clear the screen and display the winking text cursor in the upper left corner of the screen.

After getting on the air, you will then be able to take full advantage of the MicroAngelo graphics facilities, described in detail in later sections.

1.3. Driving MicroAngelo from High Level Software

If you will be driving MicroAngelo primarily from software written in a higher level language (e.g., BASIC, FORTRAN), you will find the interface very straightforward. Read the section entitled "The Software Interface", then refer to the section entitled "Sample BASIC Interface" for an example high-level interface.

BASIC SYSTEM INTEGRATION



2. Basic System Integration

The system is supplied fully assembled and tested, and is ready to insert into virtually any S100 bus computer after the port addresses have been set to be compatible with the host. (MicroAngelo can be easily adapted to non-S100 bus structures. See the section entitled "Adapting MicroAngelo to Non-S100 Systems".) As shipped, the two MicroAngelo ports are mapped as F0 and F1 in your system's port address space. Because of the way MicroAngelo interprets port addresses, however, the hardware will actually respond to 8 different ports within the group F0-FF, with port addresses F0,F4,F8,FC responding as one port, and F1,F5,F9,FD responding as the second port. Before inserting MicroAngelo into your system, therefore, verify that your system does not already currently use one of these 8 port addresses.

2.1. Changing the Port Addresses

If the MicroAngelo default port addressing is not appropriate for your system, you may move to any other 16 port boundary by altering the Port Address Jumpers J11-J14, which are located near the bottom right corner of the board. As shipped, all four jumpers are set to logic "1" by default printed circuit traces between the center and right hole. To switch a jumper to "0", scratch through the default trace and connect the center and left hole with a short length of wire. Set J11-J14 according to the following table to obtain the desired port mapping:

Desired Ports	J14	J13	J12	J11
00-0F	0	0	0	0
10-1F	0	0	0	1
20-2F	0	0	1	0
30-3F	0	0	1	1
40-4F	0	1	0	0
50-5F	0	1	0	1
60-6F	0	1	1	0
70-7F	0	1	1	1
80-8F	1	0	0	0
90-9F	1	0	0	1
A0-AF	1	0	1	0
B0-BF	1	0	1	1
C0-CF	1	1	0	0
D0-DF	1	1	0	1
E0-EF	1	1	1	0
F0-FF	1	1	1	1

For example, to map the ports in the C0-CF group, cut through the default traces on J11 and J12, and solder in a short wire between

the left and center holes on each of these two jumpers.

2.2. Connecting a TV Monitor

The final video signals are available at connector JB at the extreme top left of the board. These pins are numbered 1-6 from left to right, and deliver the following signals:

JB-1	RS-170 composite video
JB-2	ground
JB-3	direct-drive TTL video
JB-4	ground
JB-5	direct-drive, horizontal sync
JB-6	direct-drive, vertical sync

The system can drive either a composite video monitor or a direct-drive monitor, or both simultaneously. Connect a composite video monitor to JB-1, JB-2. Connect a direct-drive monitor to JB-3, JB-4, JB-5, JB-6.

After setting the port addresses and connecting the TV monitor, the MicroAngelo hardware will be fully operational in your host system, and you will then be able to install the simple software interface described in the next sections. The section entitled "System Details" describes other hardware options you may eventually wish to use.

2.3. The Software Interface

All communications between your host computer and MicroAngelo occur over the two ports which have been situated at some 16 port boundary in your system. The lower-addressed port of this pair (e.g., F0) is the Data Port, the higher-addressed port (e.g., F1) is the Control Port. The Data Port is used for communicating 8-bit data and command bytes to and from MicroAngelo, the Control Port for handshaking and for restarting Micro Angelo. Screenware Pak I is constantly monitoring these two ports in anticipation of the next graphics command or data byte.

When power is first applied to MicroAngelo, automatic restart circuitry initializes the system hardware and software. The screen is cleared, all cursors and software options described in sections below are set to their default values, and Screenware Pak I begins listening over the Data Port for a command or data.

2.3.1. Sending a Byte to MicroAngelo

The Data Port is a latched, bi-directional pathway with handshaking. "Handshaking" means that before sending a byte, the sender must first verify that the previous byte has been processed by the receiver. Without handshaking the preceding data or command byte, which may not yet have been acted upon by the receiver, might inadvertently be overwritten by the sender's next byte. A latched, handshaking port is essential when each side of the interface is an intelligent system running asynchronously with respect to the other. Handshaking applies symmetrically to both sides of the interface.

Handshaking is accomplished with MicroAngelo as follows. The rightmost bit of the Control Port byte will be "1" when there is a host command or data byte in the outbound Data Port which MicroAngelo has not yet acted upon. Thus, before sending any command or data byte over the Data Port, your system should always read the Control Port, test this "outbound buffer full" bit, and wait for it to become "0", if it is not already.

The following 8080 assembly language subroutine is the standard method of sending a data or command byte from the host's A register to MicroAngelo (without destroying any other registers):

```
dport      equ    OFOH       declare the Data Port address
cport      equ    OF1H       declare the Control Port address

sendbyte   push   psw        save the byte a moment
sdb1       in     cport      read the Control Port
           ani    1          examine the status bit
           jnz    sbd1       loop if buffer is full
           pop    psw        restore the byte to send
           out    dport      send to the Data Port
           ret               return
```

(Note that this code is exactly what would be used if you were driving a dumb terminal.) See the section entitled "Software Interface Examples" for an equivalent interface written in BASIC.

In the opposite direction, when Screenware Pak I sends the host system a response, an identical mechanism will cause Screenware Pak I to wait for the host (i.e., your software) to read the response from the Data Port before sending the next response byte.

2.3.2. Reading a Response from MicroAngelo

The second from the right bit of the Control Port indicates to the host computer whether or not there is a response byte back from MicroAngelo waiting to be read from the inbound port. When "1", this bit indicates that a response byte is ready to be read over the Data Port; "0" means there is no byte to be read. When the host reads the byte from the Data Port, this bit is automatically reset to "0" to inform Screenware Pak I that it is free to send the next response byte, if any.

The following code is the standard method of reading a response from Screenware Pak I. It waits for a response byte to enter the interface from the MicroAngelo side, then reads it and returns it in the host's A register (without altering any other registers).

```
readbyte  in    cport       read the Control Port
          ani   2           isolate the "data available" bit
          jz    readbyte    wait if no byte ready yet
          in    dport       read the byte from the Data Port
          ret               return
```

The SENDBYTE and READBYTE routines implement a complete MicroAngelo interface. In a typical CP/M-based system, these two subroutines should be coded and placed in the USER I/O area, where they can be called by higher-level system and user software to control MicroAngelo.

2.3.3. Restarting MicroAngelo

Your system can restart MicroAngelo at any time via the Control Port. By outputting a 01 byte (actually, any byte with the rightmost bit "1") to the Control Port, the host causes a hardware reset condition to begin on the MicroAngelo board. This reset will persist until a 00 byte is sent to the Control Port, and is functionally identical to the power-on reset generated by the MicroAngelo hardware at the time the system was first turned on. Immediately after the host releases the MicroAngelo from the reset, Screenware Pak I will clear the screen and reinitialize all modes and parameters to their default values. All current context will be lost.

Example code for restarting MicroAngelo is:

```
graphrst  mvi   a,1         send a "1" to the Control Port
          out   cport
```

```
        mvi   a,0
        out   cport
        ret                 return
```

You may wish to include this code in your operating system's warm- and/or cold-start initialization code so that the MicroAngelo display will be restarted each time the host goes through its own initialization sequence. On the other hand, the only condition under which you actually have to use the reset is when user software has sent an erroneous or incomplete command sequence to MicroAngelo, or when user-loaded code has lost control onboard MicroAngelo (see the UTILITY and USER commands).

2.3.4. Summary of the Control Port

To summarize, the Control Port plays two roles. Reading this port delivers the interface handshaking bits:

```
   7    6    5    4    3    2    1    0
+---------------------------------------+
! XX ! XX ! XX ! XX ! XX ! XX ! IF ! OF !
+---------------------------------------+

IF: Inbound buffer (from MicroAngelo to
    host) is full

OF: Outbound buffer (from host to Micro
    Angelo) is full

XX: Unused
```

Writing to this port controls the MicroAngelo hardware reset:

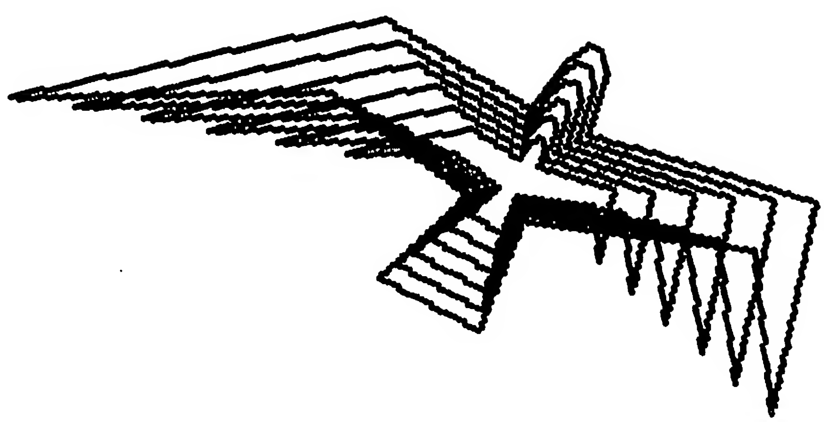
```
   7    6    5    4    3    2    1    0
+---------------------------------------+
! XX ! XX ! XX ! XX ! XX ! XX ! XX ! HR !
+---------------------------------------+

HR: "1" causes the hardware reset to begin
    "0" releases the reset condition, allowing
        MicroAngelo to restart

XX: Unused
```

SCREENWARE PAK I -

THE ONBOARD SOFTWARE



3. Screenware Pak I - the Onboard Software

Screenware Pak I responds to commands and data sent over the Data Port under the conventions described in the previous section. Screenware Pak I can be thought of as two largely independent components: ALPHA and GRAPHICS. The ALPHA (standing for "alpha-numeric") component manages the graphics display as though it were a text-only "dumb terminal". This allows you to get on the air quickly, using Micro Angelo as your system's primary output device. The GRAPHICS component recognizes a variety of graphics commands for operations such as point, vector, region and special character generation, and light pen control. Because of the way Screenware Pak I interprets commands and data, ALPHA and GRAPHICS are both always active, so that you are not forced to be in one mode or the other at each moment, as with some other types of graphics systems.

Upon receiving a byte from the host over the Data Port, Screenware Pak I first inspects the high-order bit of the byte. If this bit is "0":

```
  7   6   5   4   3   2   1   0
+--------------------------------+
! 0 !         ASCII CODE         !
+--------------------------------+
```

the byte is sent to the ALPHA processor. Since the ALPHA processor is emulating a dumb terminal, the byte will be interpreted as an ASCII character, and acted upon appropriately. If the code is a printing character, it is printed on the screen at the current ALPHA cursor, and the cursor is advanced, possibly invoking the ALPHA scrolling mechanism. Alternatively, if it is an ASCII control character (e.g., carriage-return, backspace), then the ALPHA processor takes the appropriate control action. (The specific ASCII control codes to which ALPHA responds are described below.) Thus, the ALPHA component provides a complete dumb terminal emulation.

If the high bit of a received byte is "1", the byte is interpreted as a command, with the next five high-order bits specifying the opcode. Except for opcode 0 (which relates to the dumb terminal emulator), all commands are handled by the GRAPHICS component.

The Screenware Pak I commands are:

```
  7   6   5   4   3   2   1   0
+--------------------------------+
! 1 !        OPCODE       ! MODE !
+--------------------------------+
```

Opcode	Command Name	Function
0	ALPHAMODE	select various ALPHA mode options
1	GCURSOR	set or read the graphics cursor
2	SCREEN	clear the screen, set figure/ground
3	POINT	turn on or read a point
4	VECTOR	draw a vector (line)
5	REGION	draw a rectangular region
6	CHARACTER	plot or define a graphics character
7	LIGHTPEN	turn on or off, or read the light pen
8	CROSSHAIRS	control the graphics crosshairs
9	MEMORY	dump, load screen or memory
10	UTILITY	arm USER, call user code, arm RTI
11	USER	call user-defined function
12-31	RESERVED	reserved for future use

The two rightmost bits of a GRAPHICS command byte are used in specifying a mode or subfunction within these 12 categories. The ALPHAMODE command is described below. The remaining 10 GRAPHICS commands are described in detail in later sections.

3.1. ALPHA - The Dumb Terminal Emulator

At startup time, Screenware Pak I clears the display, displays a winking text cursor in the upper left corner of the screen, and begins emulating a "dumb terminal" capable of at least a 300 character per second data rate (3000 baud equivalent) under most conditions. (The limiting factor for the data rate is the scrolling software. For applications requiring higher data rates, "rolling" instead of scrolling may work to your advantage. See the ALPHAMODE command.)

Each ASCII code your system sends over the Data Port is treated by the dumb terminal emulator as either a printing ASCII character or an ASCII control code, and will cause the appropriate screen activity to occur automatically.

3.1.1. Dumb Terminal Screen Conventions

The ALPHA processor treats the screen as a text grid of 40 lines of 85 characters per line. Row 0 is at the top, row 39 is at the bottom, column 0 is at the left, column 84 is at the right. The ALPHA CURSOR, (AR,AC), always identifies the screen position to which the next ALPHA character will be written, and is initialized at restart time to (0,0).

Characters on the screen are 12 pixels high, 6 pixels wide, and are generated by Screenware Pak I from its internal character generator table. (Appendix 2 shows this character set in detail.) However, using the CHARACTER and/or MEMORY commands, you can define a second, alternate set of 128 characters. (See the section "Defining the Alternate Character Set" for a description of this procedure.)

3.1.2. Dumb Terminal ASCII Control Codes

The ALPHA dumb terminal emulator recognizes and processes the following standard ASCII control codes:

BS (08) - Backspace (back up to and erase previous character)

HT (09) - Horizontal Tab (moves to next 8 column boundary)

LF (0A) - Line Feed (ignored)

FF (0C) - Form Feed (clears the screen)

CR (0D) - Carriage Return (also does a line feed)

ESC (1B) - Escape (causes the next ALPHA byte to be printed literally)

DEL (7F) - Delete (treated as BS)

3.1.3. Dumb Terminal Printing Options

The dumb terminal emulator can be conditioned to print text in a number of special modes. If you do not need any of these modes, no action is required. However, the following modes are available and can be selected by calls to the ALPHAMODE command described in the section entitled "MicroAngelo Commands":

1. Figure/ground (whether to print white-on-black or black-on-white characters)
2. Underlining (whether or not to underline characters as they are printed)
3. Overstrike (whether to overstrike or print as usual)

4. Font (whether to use the standard or user-defined font)

5. Cursor (whether or not the winking cursor should be displayed)

6. Scroll (how much to pop up when text would fall off the bottom of the screen)

7. Coordinates (where to print the next text character)

The defaults for these are:

1. Light characters on dark background

2. Underlining off

3. Overstrike off

4. Standard font

5. Visible cursor

6. 10-line pop-up

7. Starting cursor coordinates at row 0, column 0

See the ALPHAMODE command if you wish to change any of these defaults.

3.1.4. The Dumb Terminal Interface Code

Because of the ALPHA component's ability to emulate a standard terminal, MicroAngelo will become your system's main output device after a simple integration step. To make MicroAngelo your main output device, install the following code in your system's User area as the subroutine to be called to output the A register to the screen. In this code (which is repeated from the section entitled "Quick Integration Steps"), DPORT and CPORT refer to the two communications ports described earlier. Unless you have changed the port mapping, these are F0 and F1, respectively.

```
dport      equ    0F0H          declare the Data Port
cport      equ    0F1H          declare the Control Port

ttyout     push   psw           save the output character
tto1       in     cport         read the MicroAngelo Control Port
           ani    1             test the output status bit
           jnz    tto1          loop if interface buffer still full
```

```
        pop    psw          send the character
        out    dport        to the MicroAngelo Data Port
        ret                 return
```

If you wish warm- and/or cold-starts of your system to restart MicroAngelo, also insert the following reset code in your host system's initialization sequence(s):

```
ttyrst  mvi    a,1          send a hardware reset
        out    cport        to the Control Port
        mvi    a,0          release the reset condition
        out    cport
        ret                 return
```

3.2. GRAPHICS - The MicroAngelo Graphics System

The GRAPHICS processor is responsible for plotting points, vectors, regions and characters of special size or orientation, and for controlling the light pen interface. GRAPHICS responds to the various commands described in the section entitled "MicroAngelo Commands", and is largely independent of the ALPHA processor, which emulates a dumb, text-only terminal. The sections below describe the GRAPHICS conventions and cursors.

3.2.1. GRAPHICS Screen Conventions

The Screen is a 512 wide by 480 high grid of on/off pixels ("picture elements"). X coordinates range from 0-511 left to right, Y coordinates from 0-479 bottom to top. In the descriptions below, the term "graphics coordinate" refers to this coordinate system. Since a graphics coordinate requires 9 bits, two bytes are used when specifying a graphics coordinate to MicroAngelo. By convention, the high byte is always sent first, the low byte second. For example, to send the coordinate 293 decimal (125 hex), send a first byte of 01 hex, a second byte of 25 hex. Any graphics X coordinate larger than 511 or Y coordinate larger than 479 sent to Screenware Pak I will be clipped to its maximum value.

A pixel is "on" when a "1" bit is stored in its corresponding location in the MicroAngelo display memory. However, whether an "on" condition is seen as a light dot on a dark background or a dark dot on a light background is determined

by the setting of the screen's figure/ground hardware, described in the SCREEN primitive below.

3.2.2. GRAPHICS Cursors and Coordinates

Screenware Pak I continuously maintains six cursor and coordinate pairs:

(AR,AC) - the current row and column of the ALPHA CURSOR; AR ranges from 0-39 top to bottom, AC from 0 to 84 left to right

(AX,AY) - the graphics coordinates of the lower left pixel of the character at (AR,AC)

(CX,CY) - the main GRAPHICS CURSOR's coordinates

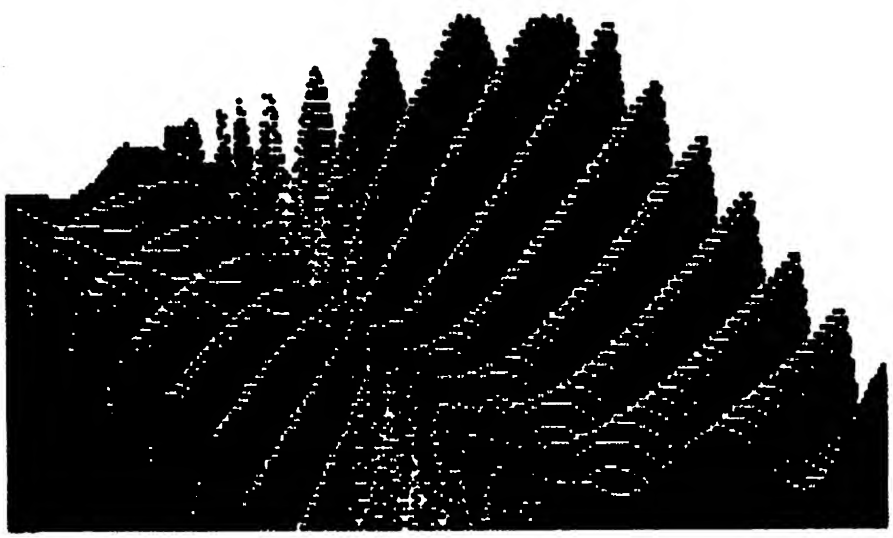
(LX,LY) - the coordinates of the most recent light pen firing

(TX,TY) - the graphics coordinates of the tracking cross

(HX,HY) - the graphics coordinates of the crosshairs

AR,AC) and (AX,AY) are maintained by the ALPHA component. The others are described in the following sections, and are all initialized to (0,0) at restart time.

MICROANGELO COMMANDS



4. MicroAngelo Commands

This section describes the 12 Screenware Pak I commands. In these descriptions the calling sequence is indicated by

CALL: <hex opcode> <byte> ... <byte>

i.e., to use the command, send the hex opcode followed by the specified byte-size parameters, all over the Data Port. MicroAngelo responses, if any, are indicated by

RESPONSE: <byte> ... <byte>

If a command generates responses, your software must always read those responses. Otherwise, Screenware Pak I will become backlogged and will eventually stop responding until any outstanding responses are read.

The first command, ALPHAMODE, is used to set the various dumb terminal printing options, and relates more to the ALPHA component than to the GRAPHICS component. The remaining 11 commands relate to MicroAngelo graphics. Appendix 1 summarizes all commands and gives decimal and octal equivalents for the opcodes.

4.1. ALPHAMODE

```
                              7   6   5   4   3   2   1   0
                            +---------------------------------+
OPCODE 0 - ALPHAMODE        ! 1 ! 0   0   0   0   0 ! M   M !
                            +---------------------------------+
```

MODE 0: SET ALPHA MODE BITS
CALL: 80 <mode>
RESPONSE: none

The ALPHA MODE word is set to the <mode> byte. The format of the ALPHA MODE word is:

```
+---------------------------------------+
! SC ! XX ! XX ! CU ! FO ! OS ! UL ! FG !
+---------------------------------------+
```

SC "0" means do not clear screen or home (AR,AC)
"1" means clear screen and home (AR,AC)
(SC is not actually stored as part of the ALPHA MODE word, but has only a one-time effect at command time.)

CU "0" enables display of the winking cursor
"1" inhibits display of the cursor

FO "0" selects the standard Screenware Pak I character set
"1" selects the user-defined character set

OS "0" selects normal erase-before-print mode
"1" selects character overstrike mode

UL "0" inhibits underlining
"1" turns on underlining

FG "0" selects light characters on dark background
"1" selects dark characters on light background

MODE 1: POSITION ALPHA CURSOR
CALL: 81 <row> <col>
RESPONSE: none

The ALPHA CURSOR is set to (<row>,<col>). This "escape sequence" allows for quick repositioning of the cursor. Subsequent text will be printed starting at the new location.

MODE 2: READ ALPHA CURSOR
CALL: 82
RESPONSE: <row> <col>

The current ALPHA CURSOR location is returned, row first then column.

MODE 3: SET ALPHA SCROLL
CALL: 83 <n>
RESPONSE: none

The ALPHA scroll parameter is set to <n>. If <n>= 0, "roll mode" is selected. In this mode, rather than popping up, the cursor wraps around to the top line and clears one line at a time in advance as it reuses the screen. This mode is fastest, since it requires no pop-up time, but can be somewhat visually confusing. If <n> is greater than 0 and less than 40, the screen will be popped up by <n> lines each time text is about to fall off the bottom. If <n> is greater than 39, the entire screen will be cleared at pop-up time, and new text begun at the top.

4.2. GCURSOR

```
                              7   6   5   4   3   2   1   0
                            +--------------------------------+
OPCODE 1 - GCURSOR          ! 1 ! 0   0   0   0   1 ! M   M !
                            +--------------------------------+
```

MODE 0: SET GRAPHICS CURSOR
CALL: 84 <xh> <xl> <yh> <yl>
RESPONSE: none

The graphics cursor (CX,CY) is set to the values specified. (<xh> is the high byte of the CX coordinate, <xl> is the low byte, <yh> is the high byte of the CY coordinate, <yl> the low byte.) The main graphics cursor is never actually visible, but serves as the relative origin of several graphics operations. (CX,CY) is automatically moved by several graphics operations.

MODE 1: READ GRAPHICS CURSOR
CALL: 85
RESPONSE: <xh> <xl> <yh> <yl>

The current (CX,CY) coordinates are reported.

MODE 2: SET (CX,CY) TO (AX,AY)
CALL: 86
RESPONSE: none

CX is set to AX, CY is set to AY. This is useful for coordinating text and graphics.

MODE 3: SET (CX,CY) TO (TX,TY)
CALL: 87
RESPONSE: none

(CX,CY) are set to (TX,TY).

4.3. SCREEN

```
                              7   6   5   4   3   2   1   0
                            +--------------------------------+
OPCODE 2 - SCREEN           ! 1 ! 0   0   0   1   0 ! M   M !
                            +--------------------------------+
```

MODE 0: CLEAR SCREEN
CALL: 88
RESPONSE: none

The display screen is cleared by turning all pixels "off". If the figure/ground has been set to light-on-dark, the screen goes completely dark. If the figure/ground has been set to dark-on-light, the screen goes completely light.

MODE 1: SET SCREEN FIGURE/GROUND
CALL: 89 <fg>
RESPONSE: none

The figure ground is set according to the rightmost bit of the following byte, <fg>. A "0" bit selects light-on-dark, a "1" bit selects dark-on-light.

MODE 2: TOGGLE SCREEN FIGURE/GROUND
CALL: 8A
RESPONSE: none

The current figure/ground is toggled. This is useful, for example, in rapid screen flashes to attract the user's attention.

MODE 3: READ SCREEN FIGURE/GROUND
CALL: 8B
RESPONSE: <fg>

The current figure/ground status is returned as the rightmost bit of the response byte.

4.4. POINT

```
                              7   6   5   4   3   2   1   0
                             +-------------------------------+
OPCODE 3 - POINT             ! 1 ! 0   0   0   1   1 ! M   M !
                             +-------------------------------+
```

MODE 0: TURN POINT OFF
CALL: 8C <xh> <xl> <yh> <yl>
RESPONSE: none

The point at the specified graphics coordinates is turned off. (CX,CY) are set to this location.

MODE 1: TURN POINT ON
CALL: 8D <xh> <xl> <yh> <yl>
RESPONSE: none

The point at the specified graphics coordinates is turned on. (CX,CY) are set to this location.

MODE 2: COMPLEMENT POINT
CALL: 8E <xh> <xl> <yh> <yl>
RESPONSE: none

The point at the specified graphics coordinates is complemented. (CX,CY) are set to this location.

MODE 3: READ POINT
CALL: 8F <xh> <xl> <yh> <yl>
RESPONSE: <val>

A byte containing only the requested pixel is returned. If this byte is zero, the point is off; if non-zero, the point is on. (CX,CY) are set to this location.

4.5. VECTOR

```
                              7   6   5   4   3   2   1   0
                            +-------------------------------+
OPCODE 4 - VECTOR           ! 1 ! 0   0   1   0   0 ! M   M !
                            +-------------------------------+
```

MODE 0: TURN VECTOR OFF
CALL: 90 <xh> <xl> <yh> <yl>
RESPONSE: none

All points lying along the vector between and including (CX,CY) and the coordinates specified in the command are turned off. (CX,CY) are set to the new endpoint after the operation.

MODE 1: TURN VECTOR ON
CALL: 91 <xh> <xl> <yh> <yl>
RESPONSE: none

All points lying along the vector between and including (CX,CY) and the coordinates specified in the command are turned on. (CX,CY) are set to the new endpoint after the operation.

MODE 2: COMPLEMENT VECTOR
CALL: 92 <xh> <xl> <yh> <yl>
RESPONSE: none

All points lying along the vector between and including (CX,CY) and the coordinates specified in the command are complemented. (CX,CY) are set to the new endpoint after the operation.

MODE 3: NO OPERATION

4.6. REGION

```
                            7   6   5   4   3   2   1   0
                          +--------------------------------+
OPCODE 5 - REGION         ! 1 ! 0   0   1   0   1 ! M   M !
                          +--------------------------------+
```

MODE 0: TURN REGION OFF
CALL: 94 <x1h> <x1l> <y1h> <y1l> <x2h> <x2l> <y2h> <y2l>
RESPONSE: none

All bits in the rectangular region identified by the diagonally opposing corner points given in the command are turned off. (CX,CY) are unaffected.

MODE 1: TURN REGION ON
CALL: 95 <x1h> <x1l> <y1h> <y1l> <x2h> <x2l> <y2h> <y2l>
RESPONSE: none

All bits in the rectangular region identified by the diagonally opposing corner points given in the command are turned on. (CX,CY) are unaffected.

MODE 2: COMPLEMENT REGION
CALL: 96 <x1h> <x1l> <y1h> <y1l> <x2h> <x2l> <y2h> <y2l>
RESPONSE: none

All bits in the rectangular region identified by the diagonally opposing corner points given in the command are complemented. (CX,CY) are unaffected.

MODE 3: NO OPERATION

4.7. CHARACTER

```
                                7   6   5   4   3   2   1   0
                              +-------------------------------+
OPCODE 6 - CHARACTER          ! 1 ! 0   0   1   1   0 ! M   M !
                              +-------------------------------+
```

MODE 0: PLOT GRAPHICS CHARACTER
CALL: 98 <c>
RESPONSE: none

The character identified by the following byte, <c>, is plotted at (CX,CY), and (CX,CY) is advanced to the position at which the next graphics character of similar type would be plotted. (CX,CY) defines where the lower left pixel of the character (with respect to the character's frame of reference) is to be plotted. The low-order 7 bits of <c> are the ACSII code of the desired character. The high-order bit identifies the font: "0" for standard, "1" for user-defined. (These are the same fonts as used by ALPHA.) The plotting of the character is carried out according to the four mode bits in the GRAPHICS MODE WORD (see MODE 1 below):

```
+---------------------------------------+
! XX ! XX ! XX ! XX ! FG ! SZ ! DD ! DD !
+---------------------------------------+
```

DD: These two bits determine the character's print direction and orientation, as follows:
- 0: left to right, character upright
- 1: right to left, character upside-down
- 2: bottom to top, character 90 degrees ccw
- 3: top to bottom, character 90 degrees cw

SZ: "0" selects normal size character (6 by 12)
"1" selects double size character (12 by 24)

FG: "0" selects light on dark figure/ground
"1" selects dark on light figure/ground

For example, to write a double-size, dark on light message up the left edge of the screen (characters 90 degrees CCW), set the mode word to 0E. Note that GRAPHICS characters plotted by this command have no relation to the ALPHA component, except that both rely on

the same fonts. Because of the added complexity, the GRAPHICS mode character plotting takes somewhat longer than ALPHA mode.

MODE 1: SET GRAPHICS CHARACTER MODE
CALL: 99 <mode>
RESPONSE: none

The GRAPHICS MODE word is set to <mode>. The modes thus defined apply to all subsequent GRAPHICS characters. (See above).

MODE 2: DEFINE ALTERNATE CHARACTER
CALL: 9A <asc> <s11> ... <s0>
RESPONSE: none

The 6 by 12 bit pattern for ASCII character code <asc> is defined and inserted into the user-defined font. The bit pattern is sent as 12 bytes <s11>,...,<s0> which represent 12 scan lines of the character, from top to bottom. Each <si> byte's low-order 6 bits define the 6 pixels across that scan line of the character. For example, to define ASCII code 13 as a bold, full-height "T", you would call Screenware Pak I as follows:

```
9A 13 3F 3F 0C 0C 0C 0C 0C 0C 0C 0C 0C 0C
```

When printed, this character would then appear on the screen as:

```
111111
111111
001100
001100
001100
001100
001100
001100
001100
001100
001100
001100
```

(of course, with a considerably squarer aspect ratio!). To install a complete user font, the UTILITY primitive's block DEPOSIT mode is faster. The user-defined font is

stored in MicroAngelo's memory beginning at address 0F940H. By depositing 12*128= 1536 continuous bytes starting at this address, you will effectively be loading the entire user-defined font in one command.

MODE 3: NO OPERATION

4.8. LIGHTPEN

```
                            7   6   5   4   3   2   1   0
                          +--------------------------------+
OPCODE 7 - LIGHTPEN       ! 1 ! 0   0   1   1   1 ! M   M !
                          +--------------------------------+
```

The light pen interface (described electrically in the section entitled "Connecting a Lightpen") provides a method of communicating with host software by pointing rather than typing. When operating, the light pen will generate pulses that are converted to coordinates by Screenware Pak I. In Screenware Pak I, the light pen software is always enabled, and is always ready to record the most recent light pen signal coordinates, (LX,LY). These coordinates are accurate to two pixels vertically and horizontally when a quality light pen is used (see the section entitled "Connecting a Light Pen").

When the "tracking cross" is turned on (and visible as a small complemented cross on the screen), any light pen activity within the vicinity of the cross is interpreted as a command to adjust the cross so that it is dead-centered under the light pen. With Screenware Pak I continuously (and at high speed) adjusting its location to remain under the light pen, the cross appears to follow the pen wherever the user moves it. When the tracking cross is enabled, its coordinates are known as (TX,TY).

The following commands deal with the light pen interface.

MODE 0: TURN TRACKING CROSS OFF
CALL: 9C
RESPONSE: none

The light pen tracking cross is removed from the screen, if present. The system powers up with the cross off.

MODE 1: TURN TRACKING CROSS ON
CALL: 9D <xh> <xl> <yh> <yl>
RESPONSE: none

If the tracking cross is on, it is turned off. The cross is then displayed at the specified coordinates, and (TX,TY) are set to this position.

MODE 2: READ TRACKING CROSS
CALL: 9E
RESPONSE: 00
or
01 <xh> <xl> <yh> <yl>

The current tracking cross coordinates, (TX,TY), are returned.

MODE 3: READ LIGHT PEN
CALL: 9F
RESPONSE: 00
or
01 <xh> <xl> <yh> <yl>

Regardless of whether or not the tracking cross is on, if the light pen has fired since the last reading via this command, a 01 byte, followed by the most recent light pen coordinates, is returned. A 00 response is returned if the light pen has not fired since the last reading. The light pen is logically reset to await another firing. This mode is useful, for example, in detecting when the user is pointing at a menu item on the screen.

4.9. CROSSHAIRS

```
                               7   6   5   4   3   2   1   0
                             +--------------------------------+
OPCODE 8 - CROSSHAIRS        ! 1 ! 0   1   0   0   0 ! M   M !
                             +--------------------------------+
```

The Screenware Pak I "crosshairs" are a full-screen vertical line and horizontal line which, when visible, intersect at the current crosshair coordinates (HX,HY). Crosshairs are useful for indicating the coordinates of the next graphics operation in an interactive design environment. The crosshairs are independent of the main graphics cursor (CX,XY) and the tracking cross and lightpen coordinates (TX,TY) and (LX,LY). However, simple user software that constantly monitors these other coordinates can logically couple the crosshairs to any of them.

MODE 0: TURN CROSSHAIRS OFF
CALL: A0
RESPONSE: none

> If the crosshairs are on, they are turned off. (HX,HY) remain as they are.

MODE 1: DRAW CROSSHAIRS
CALL: A1 <xh> <xl> <yh> <yl>
RESPONSE: none

> If the crosshairs are on, they are turned off. The crosshairs are then turned on at the specified coordinates, and (HX,HY) are set to these coordinates.

MODE 2: READ CROSSHAIRS
CALL: A2
RESPONSE: <xh> <xl> <yh> <yl>

> The current crosshair coordinates, (HX,HY), are returned.

MODE 3: DRAW CROSSHAIRS AT (CX,CY)
CALL: A3
RESPONSE: none

If the crosshairs are on, they are turned off. (HX,HY) are set to (CX,CY) and the crosshairs are drawn at this new location.

4.10. MEMORY

```
                          7   6   5   4   3   2   1   0
                        +--------------------------------+
OPCODE 9 - MEMORY       ! 1 ! 0   1   0   0   1 ! M   M !
                        +--------------------------------+
```

MODE 0: DUMP SCREEN
CALL: A4
RESPONSE: <b1> ... <b7800>

The 7800H bytes of the display screen are reported, top screen scan line first, working left to right. This command is useful for storing screen images on disk.

MODE 1: LOAD SCREEN
CALL: A5 <b1> ... <b7800>
RESPONSE: none

The 7800H bytes of the display screen are loaded, top screen scan line first, working left to right. This command will load a previously dumped screen image.

MODE 2: EXAMINE MEMORY BLOCK
CALL: A6 <nh> <nl> <ah> <al>
RESPONSE: <b1> ... <bn>

The N bytes (specified by <nh><nl>) of MicroAngelo's memory starting at the address specified by <ah><al> are reported. See the section entitled "The MicroAngelo Memory Map" for a description of how the system's memory space is allocated.

MODE 3: DEPOSIT MEMORY BLOCK
CALL: A7 <nh> <nl> <ah> <al> <b1> ... <bn>
RESPONSE: none

The memory block of specified length and starting address is loaded, using the N bytes following the command. This command is useful for loading the alternate font, and for loading user graphics code to augment Screenware Pak I. To load a complete user-defined font of 128 ASCII characters of 12 scan lines (bytes) each, say:

A7 06 00 F9 40

then write the 600H font bytes to the Data Port. (See the section entitled "Defining the Alternate Character Set" for more details.) Before loading user code via this command, see the section entitled "The MicroAngelo Memory Map".

4.11. UTILITY

```
                           7   6   5   4   3   2   1   0
                         +--------------------------------+
OPCODE 10 - UTILITY      ! 1 ! 0   1   0   1   0 ! M   M !
                         +--------------------------------+
```

MODE 0: SET USER COMMAND ADDRESS
CALL: A8 <ah> <al>
RESPONSE: none

The address of the code to be called by the USER command (opcode 11) is defined as <ah><al>. The code should have been deposited into MicroAngelo's RAM via a MEMORY command prior to this command. See the section entitled "The MicroAngelo Memory Map" before installing any user code.

MODE 1: CALL USER CODE
CALL: A9 <ah> <al> <imask> <iah> <ial>
RESPONSE: none

Screenware Pak I calls the user code at the specified address. The user code gains control of the MicroAngelo CPU, may alter all registers except the stack pointer, and can return by executing a RET instruction. (If the stack pointer is altered, Screenware Pak I should be reentered at location 0, i.e., restarted).

As the user code is called, 3 types of logical interrupts can be enabled: DFHI (Data From Host), DTHI (Data To Host), and LPI (Light Pen). (See the section entitled "Interrupts" for a description of MicroAngelo interrupts.) <imask> identifies which (if any) interrupt sources to enable:

```
   7    6    5    4    3    2    1    0
+----------------------------------------+
! XX ! XX ! XX ! XX ! XX ! LP ! DT ! DF !
+----------------------------------------+
```

LP   enable Light Pen interrupts

DT   enable Data To Host interrupts

DF   enable Data From Host interrupts

When an enabled interrupt occurs, the user interrupt handling code at the address specified by <iah><ial> will be called under the following context: (1) interrupts will be disabled, (2) an EX AF,AF', EXX sequence will have been done to save all registers, (3) the A register will contain the interrupt mask (in the format shown above) defining the source(s) of the current interrupt. After finishing, the interrupt handling code should return via the sequence EX AF,AF', EXX, EI, RET. This CALL command will permit you to install a completely independent operating system within MicroAngelo, and will give this operating system access to interrupts.

MODE 2: SWITCH REAL-TIME INTERRUPTS
CALL: AA 00
or
AA 01 <ah> <al>
RESPONSE: none

If the second byte of the command is 00, the 1/60 second real-time interval interrupts are disabled. If the second byte is 01, real-time interrupts are enabled, and will call the user-defined code at location <ah><al>. This code should protect all registers <u>on the stack</u> (i.e., not via an EX AF,AF', EXX sequence), and should return via a RETI instruction, since the real-time clock interrupt is non-maskable. Before arming or using the real-time clock, read the section entitled "Interrupts".

MODE 3: NO OPERATION

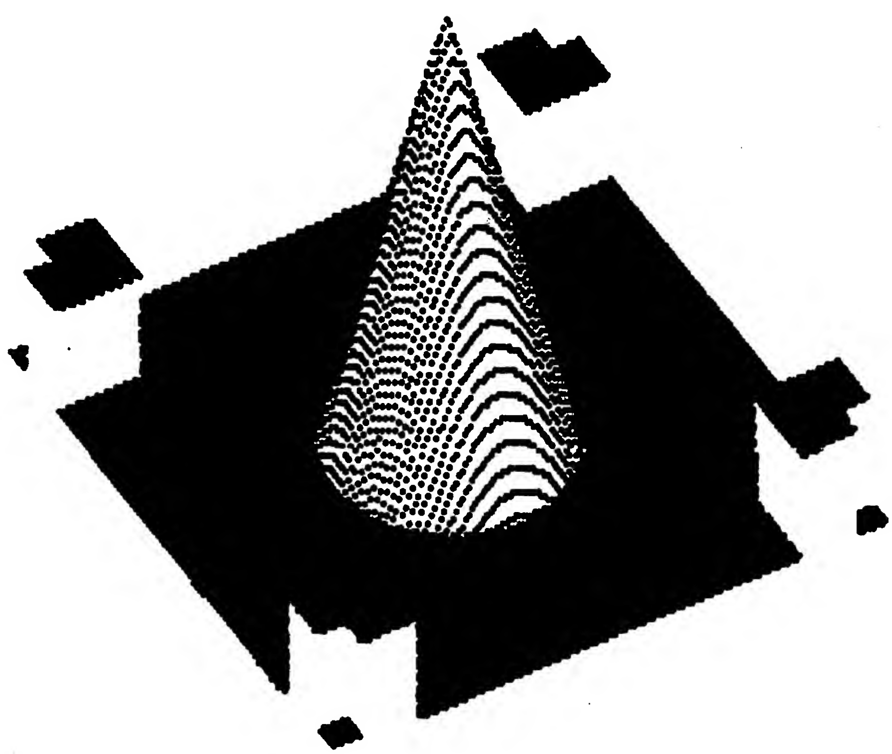
4.12. USER

```
                          7   6   5   4   3   2   1   0
                        +--------------------------------+
OPCODE 11 - USER        ! 1 ! 0   1   0   1   1 ! M   M !
                        +--------------------------------+
```

MODES 0,1,2,3: CALL USER PRIMITIVE
CALLS: AC,AD,AE,AF
RESPONSES: user-defined

This command provides a simple interface wherein user-extensions to Screenware Pak I can be called. Before using this command, first install the user code in MicroAngelo's RAM using the MEMORY command's DEPOSIT mode. Then declare the code's entry address via the UTILITY command's MODE 0. After this setup procedure, the four USER opcodes shown above will all be routed to this user code. At call time, the two mode bits (i.e., the bits that distinguish the four USER command opcodes) are available to the user code as the two rightmost bits of the B register (all other bits zero). The user code is permitted to alter any registers except the stack pointer, and should return to Screenware Pak I via a RET instruction. Before using this feature, read the section entitled "The MicroAngelo Memory Map".

SYSTEM DETAILS



5. System Details

MicroAngelo can be effectively used without a knowledge of the information in this section. However, if you wish to install a lightpen, read the subsection entitled "Connecting a Light Pen". If you plan on augmenting Screenware Pak I with additional software, read this entire section.

5.1. The MicroAngelo Memory Map

Unless you plan on sending user code across to MicroAngelo via the MEMORY command, you need not be concerned with the internal memory map of Screenware Pak I. However, in order to install and interface user-defined graphics code, it is important to understand how Screenware Pak I uses the MicroAngelo memory space.

The MicroAngelo memory map is as follows:

Region	Use
0000-0FFF	Screenware Pak I in EPROM
1000-7FFF	Unimplemented
8000-FFFF	Read-write memory, subdivided as follows:
8000-F7FF	Visible display
F800-F8BF	2 and one-half visible scan lines (which should be kept blanked)
F8C0-F93F	Screenware Pak I system stack
F940-FF3F	User-defined character generator, or user code area
FF40-FFFF	Screenware Pak I working RAM

If the alternate character set is defined and used, there is no space for user code. If, however, the alternate character set is not used (or if only a portion is used), the region F940-FF3F (1.5K bytes) can be used in whole or in part for user code.

User code should not make any unusual alterations to the system stack, nor should it alter any location in the FF40-FFFF region.

5.2. Defining the Alternate Character Set

The alternate character set resides in the F940-FF3F region of MicroAngelo's RAM. Each character symbol occupies 12 bytes, top scan line first. Thus, the region F940-F94B holds the symbol for ASCII code 0, with the top scan line at F940, the bottom line at F94B. Within each byte, the low-order six bits define the pixels across a scan line of the character. The CHARACTER and ALPHAMODE commands allow you to select this alternate character set, or toggle between the alternate and standard sets.

The alternate character set can be defined all at once by depositinging (via the MEMORY command) all 128*12 bytes starting at location F940. (If not all 128 symbols need to be defined, you need not send the entire set, and can use any remaining space for user code.) Alternatively, symbols for individual ASCII codes can be defined using the CHARACTER command's Mode 2.

As an example, suppose you wish initially to define alternate symbols for ASCII codes 0-63 (the lower half of the character set). To do this, you say:

```
A7      deposit 64*12 bytes at F940
03      64*12= 300 (hex)
00
F9      location F940
40
....    send the 768 (decimal) bytes
```

Suppose then at a later time you wish to alter the symbol for ASCII code 7. Then you say:

```
9A      define individual symbol via CHARACTER
07      ASCII code 7
....    send the twelve bytes, top scan line first
```

5.3. Interfacing Onboard User Code to Screenware Pak I

User code installed in the MicroAngelo RAM will probably need to interact with the Screenware Pak I software primitives. The separately supplied addendum to this manual entitled "Screenware Pak I User Entry Points" gives entry point addresses and calling conventions for the various user-callable Screenware Pak I functions.

5.4. The MicroAngelo Physical I/O ports

When running your own software in the MicroAngelo memory, you may occasionally wish to bypass the Screenware Pak I software and interact directly with the MicroAngelo hardware. When interacting directly with the hardware, user code has access to the following information as Z80A I/O ports 0-3:

Port	Mode	Function
0	Input	Data Port, from host
	Output	Data Port, to host
1	Input	Status Bits: 0 (rightmost bit) host-to-MicroAngelo data buffer is full 1 MicroAngelo-to-host data buffer is full 2 Light Pen strobe has fired 3 Screen Figure/Ground status 4-7 Unused
	Output	The rightmost bit sets the screen figure/ground ("0" for light on dark, "1" for dark on light). All other bits are unused
2	Input	Light Pen horizontal counter latch (left of screen is count 0, right of screen is count 255), accurate to 2 pixels
	Output	Unused
3	Input	Light Pen vertical counter latch (top of screen is count 0, bottom of screen is count 255), accurate to 2 scan lines. Reading this port also resets the light pen interface, allowing it to trigger on the next light pen strobe. (See the section entitled "Connecting a Light Pen" for more discussion.)
	Output	Unused

5.5. Interrupts

There are four potential interrupt sources for the MicroAngelo's Z80A:

DFHI (Data From Host) - the host has just written a byte to the MicroAngelo Data Port

DTHI (Data To Host) - the host has just read a byte from the Data Port

LPI (Light Pen) - the light pen has just fired

RTI (Real-Time) - the 60 hz interval timer has just fired

The first three interrupt sources are connectable as maskable Z80A interrupts. The Real-Time Interrupt, when enabled by a hardware jumper, will generate a Z80 NMI (non-maskable interrupt) every 1/60 second.

5.5.1. Enabling/Disabling the Maskable Interrupts

As shipped, only the LPI and DFHI are physically enabled. The DTHI has been disabled by removing U59 pin 9 from its socket. Reinsert this pin to enable the DTHI. (Doing so will not logically interfere with Screenware Pak I's logical operation. However, it will slow the software down somewhat when sending responses back to the host.)

To disable the DFHI, remove U59 pin 10 from its socket. To disable the LPI, remove U59 pin 13 from its socket. (Do not disable these, however, unless you are installing a completely new operating system in EPROM! Screenware Pak I assumes that these two interrupts are enabled, and will not run properly with them disabled.) See the UTILITY command (Mode 1) for a description of the logical user interface to these three maskable interrupts.

5.5.2. Enabling the Real-Time Interrupt

The RTI non-maskable interrupt can be enabled by scratching through the default trace between holes 2 and 3 of J3, and jumpering holes 1 and 2 together. After this procedure, a non-maskable interrupt will be generated every 1/60 second. See the UTILITY command (Mode 2) for a description of the logical

user interface to this non-maskable interrupt.

It should be noted that with the RTI connected, there is a very remote possibility that MicroAngelo will not power up correctly. Immediately after beginning, the Screenware Pak I software stores a specific code in one byte of its read-write memory to remind itself that RTI interrupts are logically disabled. If, however, an RTI occurs in the several microseconds between powering on and storing this disabling code, and if the MicroAngelo memory randomly happens to power up with this special code already present in the RTI enabling byte (<u>very</u> unlikely), then Screenware Pak I will erroneously branch to what it thinks is the user-defined RTI handling code. This, of course, would cause the system to lose control. To be absolutely certain that MicroAngelo has powered up correctly with the RTI enabled, use the MEMORY command to examine the RTI logical status byte at location FFC5 immediately after system power-on (i.e., put this in your cold-start initialization code). If this byte is not OCCH, keep resetting MicroAngelo (over the Control Port) until it is. Then reset the system one final time. (The chance of a bad power-up because of these circumstances is quite remote. You can therefore get along without these procedures for all but the most critical applications.)

5.5.3. <u>Connecting Host-Side Interrupts</u>

Jumper J5 on the MicroAngelo board can be set so that the <u>host</u> will be interrupted whenever MicroAngelo reads or writes a byte over the Data Port. J5 Pin 5 goes to logic "0" when MicroAngelo writes a byte to the host. J5 Pin 10 goes to logic "0" when MicroAngelo reads a byte from the host (i.e., when the host can write another byte to MicroAngelo). J5 Pins 6,1,7,2,8,3,9,4 connect to the S100 bus vectored interrupt lines (S100 fingers 4-11, respectively). By jumpering J5 Pin 5 and/or J5 Pin 10 to these vectored interrupt lines, you can route these two interrupt signals to the host CPU, if it is equipped to process them. Doing so permits the host operating system software to support an interrupt-driven protocol with MicroAngelo.

5.6. <u>Connecting a Light Pen</u>

Connector JA at the top right corner of the board is the Light Pen Connector. Pin 1 accepts the rising edge triggered Light Pen Strobe, Pin 2 is the Light Pen Ground connection, Pin 3 accepts the active high Light Pen Enable, and Pin 4 is a regulated +5 volt, 100 ma power source for the light pen. When Pin 3 is at logic "1" and a positive edge occurs on Pin 1, the

light pen hardware latch captures the display counters to record the X-Y location of the light pen. Further positive edges at Pin 1 will not be honored until Screenware Pak I software (or user software) reads the counter value from the light pen hardware latch. As shipped, both Pin 1 and Pin 3 are pulled down to logic "0" (by resistors R18, R19, respectively) in the absence of a real light pen interface.

If you wish to connect a light pen that generates both the strobe and enable signals, simply connect all 4 pins as described. (If your light pen is of the low-power type, you may have to remove R18 and R19, since these pull-down resistors may present an excessive current drain to the light pen.) If your light pen has no enable line, jumper Pin 3 and Pin 4 together to enable the light pen permanently.

See the LIGHTPEN command and the section entitled "Interrupts" for descriptions of the logical light pen interface and light pen interrupts.

5.7. Summary of Hardware Jumper Options and Connectors

There are 15 jumpers and 3 connectors on the MicroAngelo board. The tables and diagram below summarize and describe these. For most applications there will be no need to alter any jumpers. Default settings are indicated with asterisks.

5.7.1. Hardware Jumpers

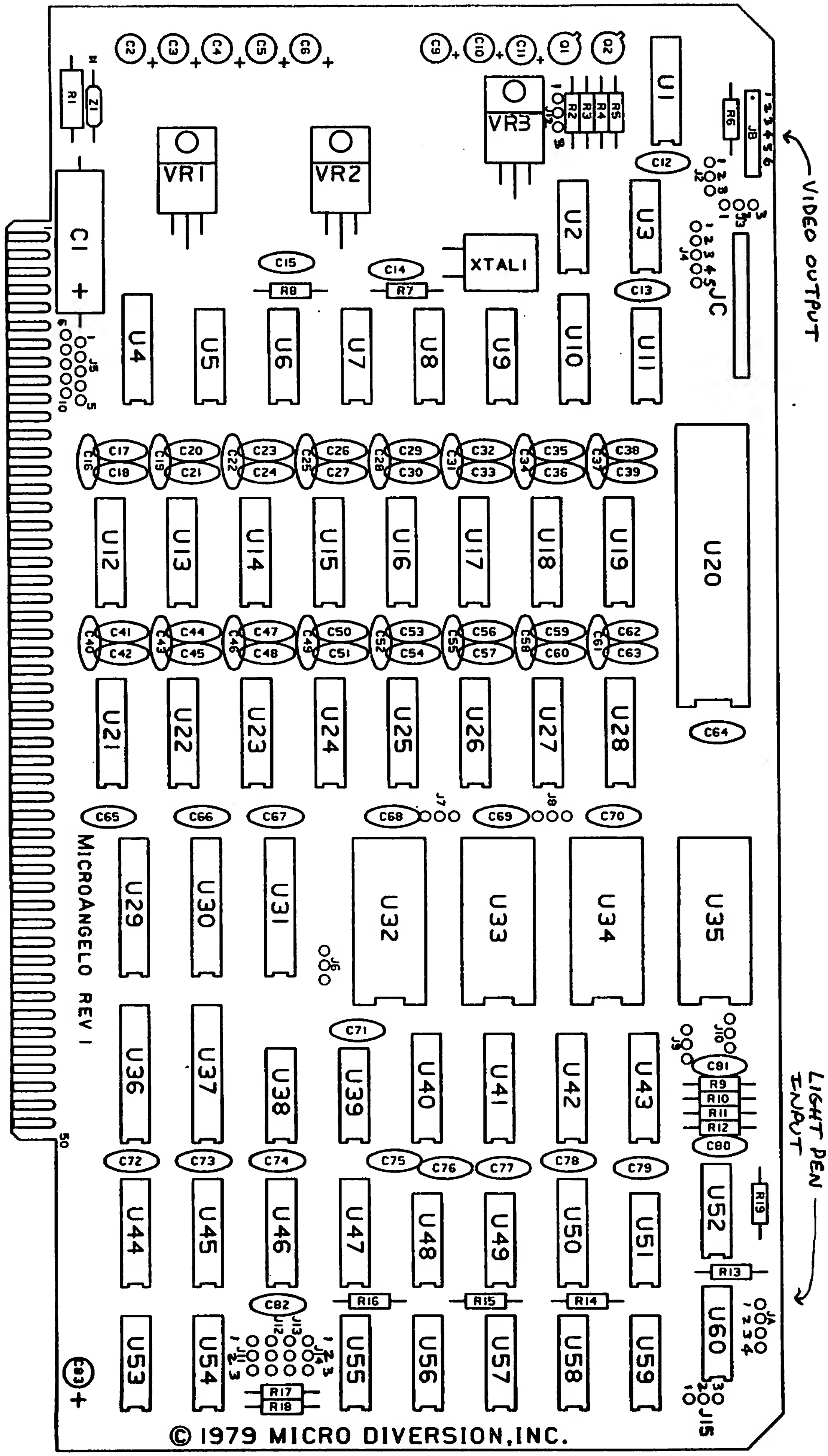
Name	Pins	Function
J1	1-2*	Select 480 visible scan lines
	2-3	Select 448 visible scan lines (Note that all Screenware Pak I software assumes that there are 480 visible lines. If you select the 448 option, you must assume responsibility for managing the display screen.)
J2	1-2*	Select 4 mhz Z80A operation
	2-3	Select 5 mhz Z80A operation A Z80A can usually run at 5 mhz. If you want to increase the speed of the system, select this option.

J3	1-2 2-3*	Enable 60 hz Real-Time Interrupt (RTI) Disable 60 hz RTI See the section entitled "Interrupts"
J4		(reserved for color interface)
J5		Holes 6,1,7,2,8,3,9,4 connect to S100 bus fingers 4,5,6,7,8,9,10,11, respectively. (These are the vectored interrupt lines.) The signal at hole 5 is the inverted DTHI interrupt, the signal at hole 10 is the true DFHI signal (see the section entitled "Interrupts"). By connecting DTHI-inverted and/or DFHI-true to vectored interrupt lines, you can arrange for your host system to be interrupted whenever MicroAngelo reads the byte last sent from the host, or sends a byte to the host. (See the section entitled "Interrupts".) The board is shipped with neither interrupt source connected.
J6-J10		(These jumpers will allow future EPROM upgrade to an 8K operating system)
J11-J14	1-2 2-3*	Select port address bit= "0" Select address bit= "1" These four jumpers map the two parallel ports over which you communicate with MicroAngelo. See the section entitled "Changing the Port Addresses".
J15	1-2* 2-3	Enable DFHI and DTHI interrupts Disable DFHI and DTHI interrupts This jumper can cause the MicroAngelo Z80A to be interrupted by communications activities with the host, as described in the section entitled "Interrupts"

5.7.2. Hardware Connectors

Name	Pin	Function
JA	1	Light Pen Strobe. A positive-going signal on this pin causes the Screenware Pak I software to update (LX,LY), the light pen

		coordinates
	2	Light Pen Ground.
	3	Light Pen Enable. A logic "1" on this pin physically enables the Light Pen Strobe. It is typically fed by the activation switch in the light pen.
	4	+5 volt, 100 ma power source for light pen
JB	1	Composite Video. Connect a composite video TV monitor to this pin and Pin 2.
	2	Composite Video Ground
	3	TTL Video. Connect a direct-drive video monitor to this and Pins 4,5,6
	4	Direct-Drive Ground
	5	Direct-Drive Horizontal Sync
	6	Direct-Drive Vertical Sync
JC	1-20	(Reserved for color interface)


VIDEO OUTPUT
LIGHT PEN INPUT
MICROANGELO REV I
© 1979 MICRO DIVERSION, INC.

5.8. Adapting MicroAngelo to Non-S100 Bus Systems

Interfacing MicroAngelo to non-S100 bus systems is relatively straightforward because of its simple parallel port connection to the host system. Specifically, MicroAngelo requires the following S100 bus connections:

S100 Pin	Name	Function
1,51	+8	Unregulated +8 volt power (2 amps)
50,100	GND	Ground
2	+18	Unregulated +18 volt power (1 amp)
52	-18	Unregulated -18 volt power (100 ma)
90	DO7	Outbound data line 7
40	DO6	Outbound data line 6
39	DO5	Outbound data line 5
38	DO4	Outbound data line 4
89	DO3	Outbound data line 3
88	DO2	Outbound data line 2
35	DO1	Outbound data line 1
36	DO0	Outbound data line 0
43	DI7	Inbound data line 7
93	DI6	Inbound data line 6
92	DI5	Inbound data line 5
91	DI4	Inbound data line 4
42	DI3	Inbound data line 3
41	DI2	Inbound data line 2
94	DI1	Inbound data line 1
95	DI0	Inbound data line 0
83	A7	Address line 7
82	A6	Address line 6
29	A5	Address line 5
30	A4	Address line 4
80	A1	Address line 1
79	A0	Address line 0
46	SINP	Input request
45	SOUT	Output request
78	PDBIN	Input strobe
77	PWR-BAR	Output strobe

The data input and output lines can be tied together to form one 8 line bidirectional data bus. Commands and data are written to MicroAngelo on the coincidence of SOUT="1", PWR-BAR="0" and Board Select. Responses and status flags are read from MicroAngelo on the coincidence of SINP="1", PDBIN="1" and Board Select. Board Select occurs when address lines A7-A4 match the settings of jumpers J14-J11 and A1="0". On a read or write operation, address line A0 determines whether the Data Port or Control Port is selected.

For a stand-alone environment in which MicroAngelo will be

powered by its own power supply and will be unrelated to its host's address space, a simple bidirectional parallel port interface can be implemented as follows:

1. Tie the data inbound and outbound lines together and route them to the host as the 8 bit bidirectional parallel I/O port.

2. Tie A7,A6,A5,A4 permanently high (to match the default jumpers J14-J11), and tie A1 permanently low.

3. Tie PDBIN permanently high, PWR-BAR permanently low.

4. Route A0 to the host as the Data/Control Port select line (i.e., MicroAngelo looks like 2 logical I/O ports over one physical I/O port connection).

5. Route SINP and SOUT to the host as the input and output command lines.

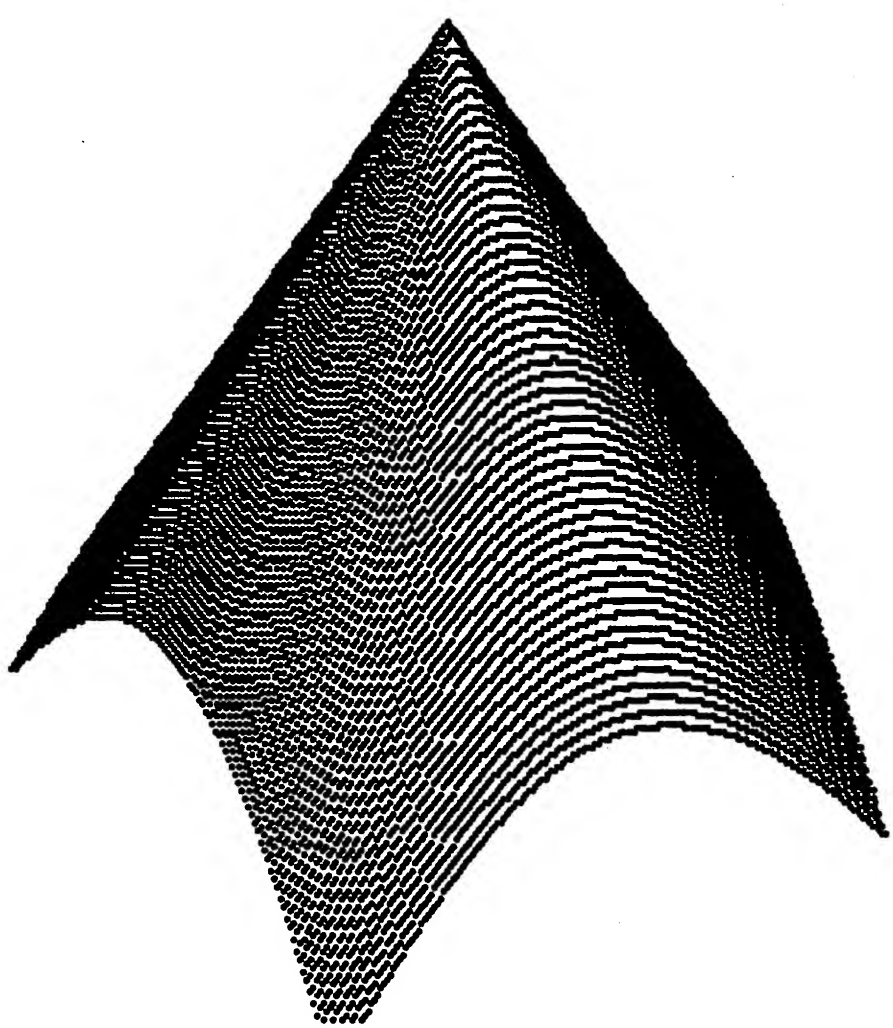
Using this 12 conductor logical interface to the host (8 data lines, A0, SINP, SOUT, ground), MicroAngelo becomes a stand-alone graphics computer compatible with virtually any type of host system. By connecting the interrupt lines as described in the section entitled "Interrupts" and routing them to the host, the interface can also support a full interrupt protocol.

5.9 <u>Bit Mapping of Display RAM to Video Screen</u>

The address space of the MicroAngelo from locations 8000 to OF7FF is RAM memory that is displayed on the video screen. Each of the 245,670 bits within this range appears as a single picture element (pixel) on the screen. These bits are mapped onto the screen in a predefined way by the MicroAngelo hardware. The top leftmost point on the display is the most significant bit of the byte stored at location 8000. The point immediately to its right is the 2nd most significant bit of the byte at 8000. This continues for all the bits in byte 8000 and then proceeds on across the screen with the bits from byte 8001, then 8002, 8003, etc. for a total of 64 bytes. The second display row then begins with the most significant bit from the byte at location 8040. The bottom rightmost bit of the display is the least significant bit of the byte at location OF7FF. The MEMORY commands "examine" and "deposit" can be used for experimenting with the direct modification of the video display.

```
        +------------------------------------------------+
  479 - !7654321076543210     . . .              76543210!
        !:        :                                     :  !
        !:        :..(byte 8001)    (byte 803F)..:  !
        !:                                               !
        !:..(byte 8000)                                  !
Y-Axis  !                                                !
        !                  VIDEO DISPLAY                 !
        !                                                !
        !                                                !
        !...(byte F7C0)             (byte F7FF)...       !
        !:                                      :        !
  000 - !76543210             . . .              76543210!
        +------------------------------------------------+
         I                                              I
        000                                            511
                          X - Axis
```

SOFTWARE INTERFACE EXAMPLES



6. Software Interface Examples

Send and receive all bytes in these examples using the code shown in the section entitled "The Software Interface".

6.1. Graphics: Clear Screen, Draw Triangle, Embed in Region

```
88      clear the screen
84      set the graphics cursor to (128,128) decimal
00
80
00
80
91      draw vector to (256,384)
01
00
01
80
91      draw a vector to (384,128)
01
80
00
80
91      draw a vector to (128,128)
00
80
00
80
96      embed triangle in region by complementing
00      make the region corners (64,64) and (448,448)
40
00
40
01
C0
01
C0
```

6.2. Turn on and Read the Tracking Cross

```
9D      turn the tracking cross on at screen center
01      X= 256
00
00      Y= 242
F2
....    (wait for user to drag it to destination,
         then type a key on the host keyboard)
9E      read the location

....    (Screenware Pak I will send the coordinates
         as four response bytes which you then read.)
```

6.3. Write a Message Around the Border of a Square

This code writes the characters "MicroAngelo!" in a box shape (i.e., "Mic" is on the top, "roA" is on the right side going down, "nge" is upside-down from right to left on the bottom, and "lo!" is on the left side going up. Characters are double size and reversed figure/ground.

```
84      move the graphics cursor to to screen center
01
00
00
F2
99      set graphics character mode for top characters
0C      reversed figure/ground, double size
98      print "M"
4D
98      print "i"
69
98      print "c"
63
99      select new orientation
0F      90 degrees cw, top to bottom
98      print "r"
72
98      print "o"
6F
98      print "A"
41
99      select new orientation
0D      upside-down, right to left
```

```
98      print "n"
6E
98      print "g"
67
98      print "e"
65
99      select new orientation
0E      90 degrees ccw, bottom to top
98      print "l"
6C
98      print "o"
6F
98      print "!"
21
```

6.4. Underlining in Dumb Terminal Mode

The following code prints the message "Hello there" by switching into and out of ALPHA Underline Mode for a moment.

```
48      print "H"
65      print "e"
6C      print "l"
6C      print "l"
6F      print "o"
20      print space
80      give ALPHAMODE command to start underlining
02      second-from-right bit governs underlining
74      print "t"
68      print "h"
65      print "e"
72      print "r"
65      print "e"
80      turn off underlining
00
```

6.5. Sample BASIC Interface

Most high level graphics software is best developed in a higher level language. To illustrate how to drive MicroAngelo from North Star BASIC, four functions, FNO, FNI, FNS and FNR are shown below. FNO will wait for the Control Port to indicate a ready-to-send condition, then send a single given byte to

MicroAngelo. FNI will await a single byte MicroAngelo response, then return it as the functional value. FNS will send a 16 bit quantity (e.g., a coordinate or address), high order byte first, by two calls on FNO. FNR will assemble a 16 bit (two byte) response from MicroAngelo and return the 16 bit quantity as its functional value. In these examples it is assumed that the Control Port is F1 and the Data Port is F0 (241, 240 decimal, respectively). If you have changed the port addresses, substitute these with the appropriate port numbers.

```
10100 REM SEND A BYTE TO MICROANGELO
10200 DEF FNO(X)
10300 I= INP(241)
10400 IF I <> 2*INT(I/2) THEN 10300
10500 OUT 240,X
10600 RETURN 0
10700 FNEND
```

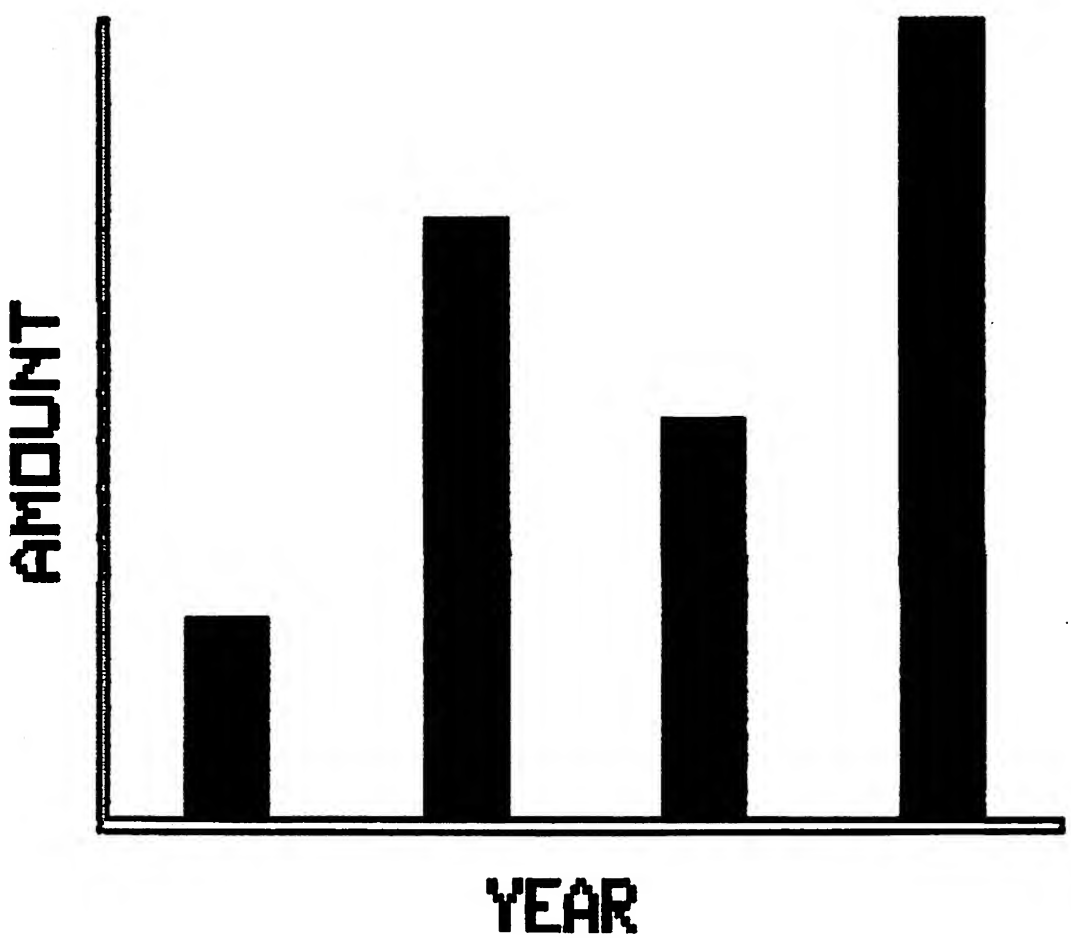
```
10800 REM READ A BYTE FROM MICROANGELO
10900 REM (CALL WITH A DUMMY PARAMETER)
11000 DEF FNI(X)
11100 I= INT(INP(241)/2)
11200 IF I = 2*INT(I/2) THEN 11100
11300 RETURN INP(240)
11400 FNEND
```

```
11500 REM SEND A 16 BIT QUANTITY TO MICROANGELO
11600 DEF FNS(X)
11700 I= FNO(INT(X/256))
11800 I= FNO(X-256*INT(X/256))
11900 RETURN 0
12000 FNEND
```

```
12100 REM READ A 16 BIT QUANTITY FROM MICROANGELO
12200 REM (CALL WITH A DUMMY PARAMETER)
12300 DEF FNR(X)
12400 Q= FNI(0)
12500 RETURN 256*Q+FNI(0)
12600 FNEND
```

Other higher level language interfaces would be similar.

APPENDICES



Appendix 1 - Summary of GRAPHICS Commands

Hex	Dec	Oct	Call/Response	Function
ALPHAMODE				
80	128	200	C: <mode> R: none	Set Alpha Mode Bits
81	129	201	C: <row> <col> R: none	Position Alpha Cursor
82	130	202	C: none R: <row> <col>	Read Alpha Cursor
83	131	203	C: <n> R: none	Set Alpha Scroll
GCURSOR				
84	132	204	C: <xh> <xl> <yh> <yl> R: none	Set Graphics Cursor
85	133	205	C: none R: <xh> <xl> <yh> <yl>	Read Graphics Cursor
86	134	206	C: none R: none	Set (CX,CY) to (AX,AY)
87	135	207	C: none R: none	Set (CX,CY) to (TX,TY)
SCREEN				
88	136	210	C: none R: none	Clear Screen
89	137	211	C: <fg> R: none	Set Screen Figure/Ground
8A	138	212	C: none R: none	Toggle Screen Figure/Ground
8B	139	213	C: none R: <fg>	Read Screen Figure/Ground
POINT				
8C	140	214	C: <xh> <xl> <yh> <yl> R: none	Turn Point Off
8D	141	215	C: <xh> <xl> <yh> <yl> R: none	Turn Point On
8E	142	216	C: <xh> <xl> <yh> <yl> R: none	Complement Point
8F	143	217	C: <xh> <xl> <yh> <yl> R: <val>	Read Point

VECTOR

90	144	220	C: <xh> <xl> <yh> <yl> R: none	Turn Vector Off
91	145	221	C: <xh> <xl> <yh> <yl> R: none	Turn Vector On
92	146	222	C: <xh> <xl> <yh> <yl> R: none	Complement Vector

REGION

94	148	224	C: <x1h> <x1l> <y1h> <y1l> <x2h> <x2l> <y2h> <y2l> R: none	Turn Region Off
95	149	225	C: <x1h> <x1l> <y1h> <y1l> <x2h> <x2l> <y2h> <y2l> R: none	Turn Region On
96	150	226	C: <x1h> <x1l> <y1h> <y1l> <x2h> <x2l> <y2h> <y2l> R: none	Complement Region

CHARACTER

98	152	230	C: <c> R: none	Plot Graphics Character
99	153	231	C: <mode> R: none	Set Graphics Character Mode
9A	154	232	C: <asc> <s11> ... <s0> R: none	Define Alternate Character

LIGHTPEN

9C	156	234	C: none R: none	Turn Tracking Cross Off
9D	157	235	C: <xh> <xl> <yh> <yl> R: none	Turn Tracking Cross On
9E	158	236	C: none R: <xh> <xl> <yh> <yl>	Read Tracking Cross
9F	159	237	C: none R: 00 or 01 <xh> <xl> <yh> <yl>	Read Light Pen

CROSSHAIRS

A0	160	240	C: none R: none	Turn Crosshairs Off
A1	161	241	C: <xh> <xl> <yh> <yl>	Draw Crosshairs

			R: none	
A2	162	242	C: none	Read Crosshairs
			R: <xh> <xl> <yh> <yl>	
A3	163	243	C: none	Draw Crosshairs at (CX,CY)
			R: none	

MEMORY

A4	164	244	C: none	Dump Screen
			R: <b1>...<b7800>	
A5	165	245	C: <b1>...<b7800>	Load Screen
			R: none	
A6	166	246	C: <nh> <nl> <ah> <al>	Examine Memory Block
			R: <b1>...<bn>	
A7	167	247	C: <nh> <nl> <ah> <al> <b1>...<bn>	Deposit Memory Block
			R: none	

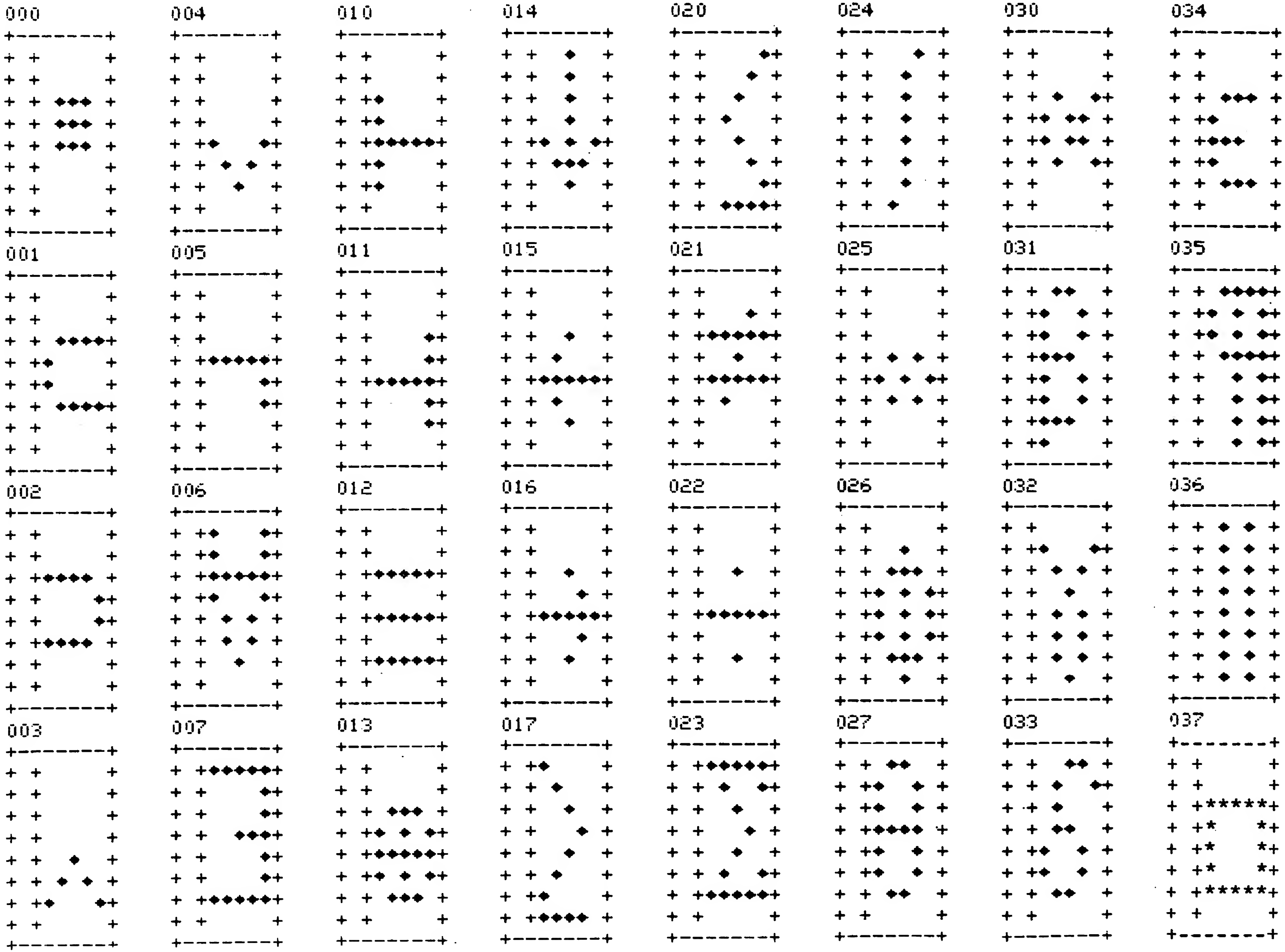
UTILITY

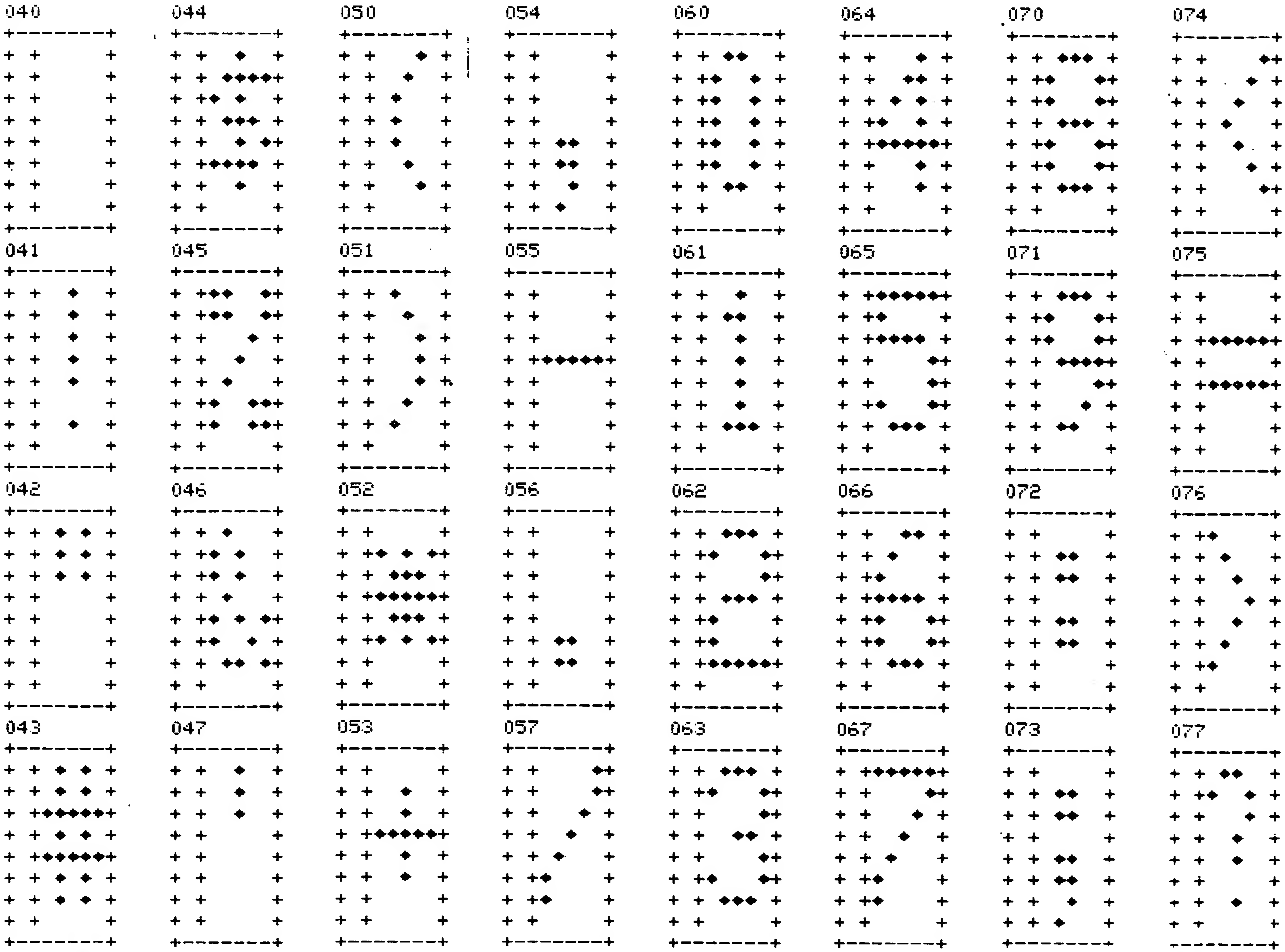
A8	168	250	C: <ah> <al>	Set User Command Address
			R: none	
A9	169	251	C: <ah> <al> <imask> <ih> <il>	Call User Code
			R: none	
AA	170	252	C: A7 00 or AA 01 <ah> <al>	Switch Real-Time Interrupts
			R: none	

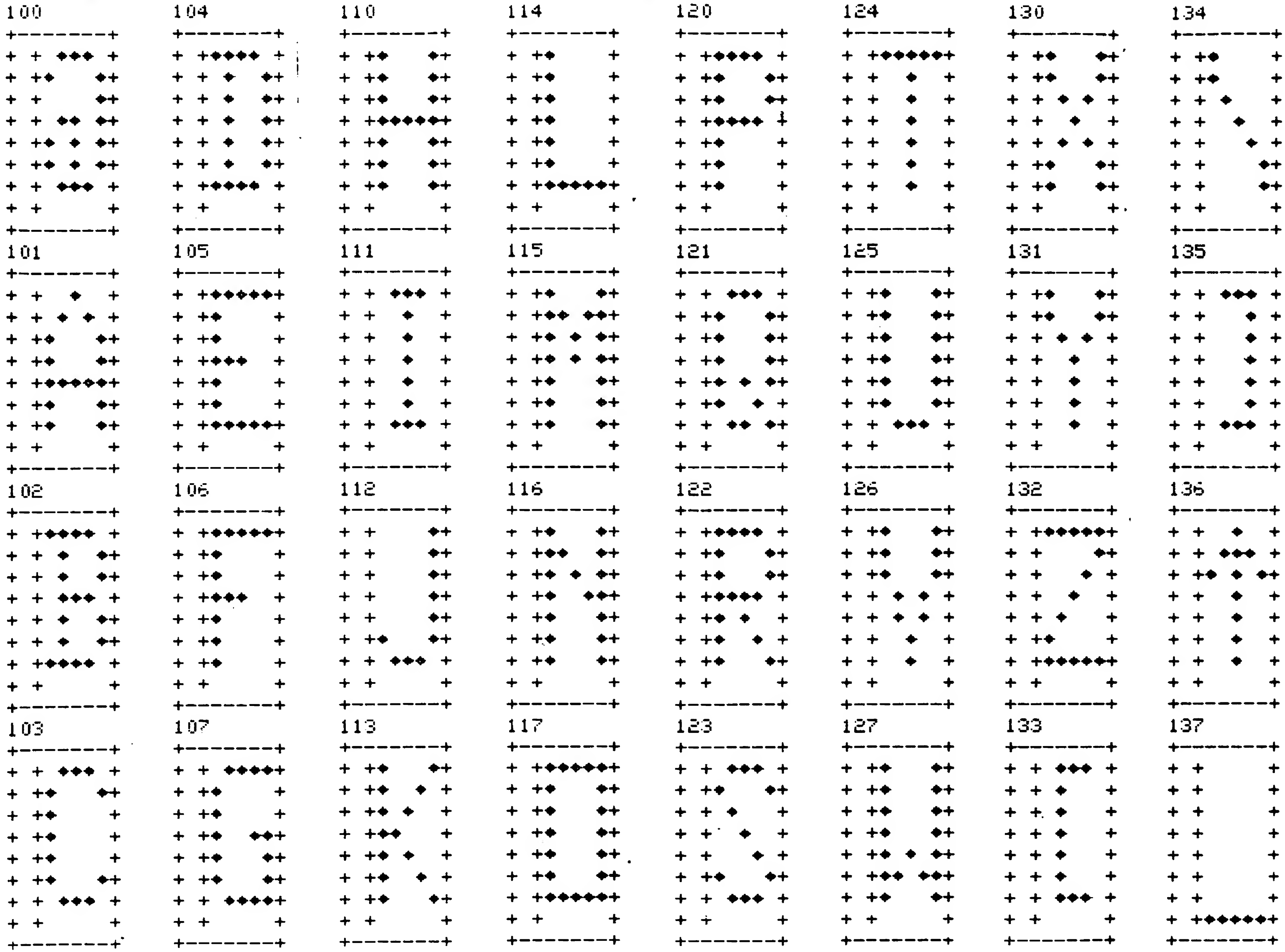
USER

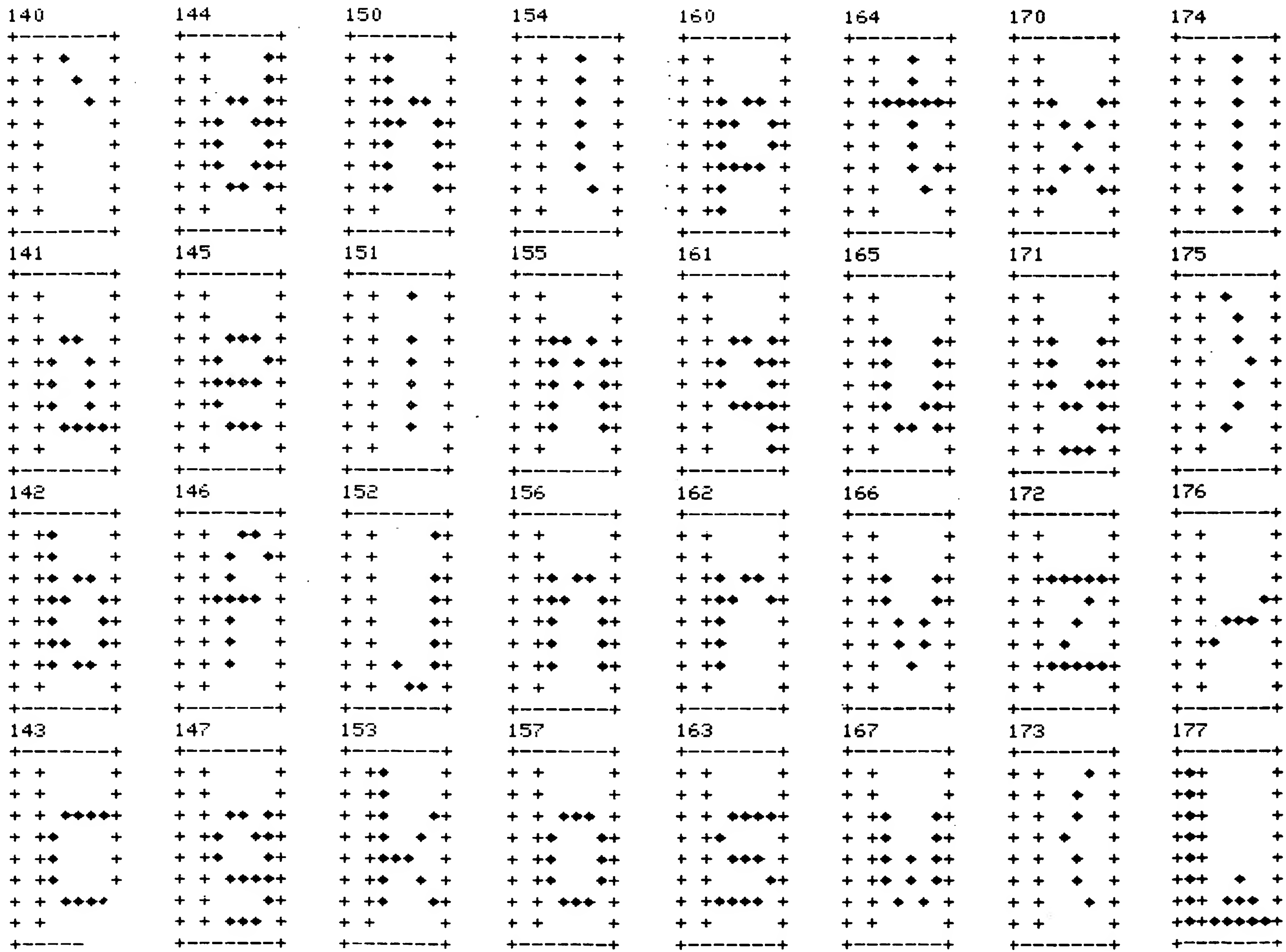
AC	172	254	C: (user defined)	User
			R: (user defined)	
AD	173	255	C: (user defined)	User
			R: (user defined)	
AE	174	256	C: (user defined)	User
			R: (user defined)	
AF	175	257	C: (user defined)	User
			R: (user defined)	

Appendix 2 - The Standard Character Font


000
004
010
014
020
024
030
034
001
005
011
015
021
025
031
035
002
006
012
016
022
026
032
036
003
007
013
017
023
027
033
037


040
041
042
043
044
045
046
047
050
051
052
053
054
055
056
057
060
061
062
063
064
065
066
067
070
071
072
073
074
075
076
077


100
104
110
114
120
124
130
134
101
105
111
115
121
125
131
135
102
106
112
116
122
126
132
136
103
107
113
117
123
127
133
137


140 144 150 154 160 164 170 174
141 145 151 155 161 165 171 175
142 146 152 156 162 166 172 176
143 147 153 157 163 167 173 177

Appendix 3

Screenware™ Pak I Internal Entry Points
SCION Corporation
June 1980 (Refer to MicroAngelo Users Manual)

SYSTEM 0000H
entry: none
exit: none
destroys: NA
description: call here to restart the system as it would be at cold-start

READBUF 012FH
entry: none
exit: carry flag set if a byte is available, cleared otherwise; if carry set, (A) = byte from host
destroys: A, D, E, H, L
description: call here to read a byte from the host (via the interrupt buffered interface) if a byte is available

GETBYTE 01A4H
entry: none
exit: (A) = byte from host
destroys: none
description: call here to read a byte from the host; GETBYTE waits until a byte is available

GETCOORD 005BH
entry: none
exit: (HL) = coordinate from host (sent high byte first)
destroys: H,L
description: call here to read a 9-bit coordinate from the host; the high 7 bits of H are zeroed

GETYCORD 0197H
entry: none
exit: (HL) = 9-bit coordinate clipped to 479
destroys: A
description: call here to read a 9-bit coordinate from the host; the coordinate is clipped to 479 if it is larger

GETADDR 038FH
entry: none
exit: (HL) = 16 bit address from host (sent high byte first)
destroys: A
description: call here to get a 16 bit quantity from the host

SENDBYTE 0259H
entry: (A) = byte
exit: none
destroys: B
description: call here to send a byte to the host; SENDBYTE waits until the outbound buffer is clear before sending

SENDCOORD 0254H
entry: (HL) = 16 bit value to send to host

```
        exit:  none
    destroys:  B
 description:  call here to send 16 bits (high order byte first) to the host

DPYLOC         021BH
       entry:  (DE) = X coordinate (0-511)
               (HL) = Y coordinate (0-479)
        exit:  (A)  = bit mask
               (B)  = bit mask
               (C)  = bit number (0 leftmost, 7 rightmost)
               (HL) = display buffer address
    destroys:  D,E
 description:  call here to convert coordinates into a Z80 memory address (on the
               visible screen) and bit mask; the bit mask (containing one on bit)
               identifies the pixel within the address byte; the bit number is the
               position of the ON bit within the byte

SCREENC        01AFH
       entry:  (A) = mode (0,1,2)
        exit:  none
    destroys:  all
 description:  call here for SCREEN command, as described in the manual; do not call
               with mode = 3, since this mode will try to read a byte from the host

POINT          01F7H
       entry:  (B)  = mode (0,1,2)
               (DE) = X coordinate
               (HL) = Y coordinate
               (CX) = X coordinate
               (CY) = Y coordinate
        exit:  none
    destroys:  all
 description:  call here for the POINT command, as described in the manual; do not
               call with mode = 3, since the code will then send a response to the
               host

VECTOR         0547H
       entry:  (B)  = mode
               (DE) = x coordinate
               (NEWCX) = x coordinate
               (HL) = y coordinate
               (NEWCY) = y coordinate
        exit:  none
    destroys:  all
 description:  call here for the VECTOR commands, as described in the manual

REGION         0275H
       entry:  enter via the following code sequence:

                       LXI   H,RETURN
                       PUSH H
                       MVI   B,<mode>
                       PUSH B
```

```
                 LXI   H,<Y1>
                 PUSH  H
                 LXI   H,<X2>
                 PUSH  H
                 LXI   D,<X1>
                 LXI   H,<Y2>
                 JMP   REGION
         RETURN: ...
```

exit: none
destroys: all
description: call via the given sequence for the REGION commands, as described in the manual

CHAR 03E7H
entry: (A) = character or character mode bits
(B) = command mode (0,1,2)
exit: none
destroys: all
description: call here for the CHARACTER commands, as described in the manual; the command mode bits select plot character, set character mode, and define alternate characters; character mode bits are as describe in the manual

DRAWCROSS 068EH
entry: (TX) = X coordinate
(TY) = Y coordinate
exit: none
destroys: all
description: call here to complement the bits on the tracking cross at (TX,TY), (i.e., if the cross is on at (TX,TY), turn it off, and vice versa)

DRAWHAIRS 07A2H
entry: (HX) = X coordinate
(HY) = Y coordinate
exit: none
destroys: all
description: call here to complement the bits on the crosshairs at (HX,HY) (i.e., if the cross hairs are on, turn them off, and vice versa)

ALPHINIT 07D9H
entry: none
exit: none
destroys: all
description: call here to reset the alpha interface: (clears the screen and sets AX, AY to top left of screen)

TTYCHAR 07EBH
entry: (A) = ASCII code
exit: none
destroys: all
description: call here to print an ASCII character at AX, AY (TTYCHAR does not advance AX, AY)

TTY 08EFH

entry: (A) = ASCII code

exit: none

destroys: all

description: call here to send an ASCII code to the ALPHA processor; control codes are recognized as described in the manual, and AX, AY are advance, possibly invoking the scrolling mechanism

Variables and Parameters:

Variable	Addr	#Bytes	Description
CX	FFFB	2	the current graphics X coordinate
CY	FFF9	2	the current graphics Y coordinate
NEWCX	FFE9	2	(see the VECTOR entry point)
NEWCY	FFE7	2	(see the VECTOR entry point)
AX	FFD0	2	the current ALHPA screen X coordinate
AY	FFCE	2	the current ALHPA screen Y coordinate
AR	FFCD	1	the current ALHPA row number
AC	FFCC	1	the current ALHPA column number
ALPHSCRL	FFCB	1	the current ALPHA scroll parameter
ALPHMODE	FFCA	1	the current ALPHA mode bits
CHARMODE	FFC9	1	the current GRAPHICS character mode bits
TX	FFD4	2	the current tracking cross X coordinate
TY	FFD2	2	the current tracking cross Y coordinate
TSTAT	FFD6	1	1 if the tracking cross is visible, 0 otherwise (The DRAWCROSS entry point does not maintain this cell - you should do it manually when calling DRAWCROSS)
LPX	FFFE	1	the (X coordinate/2) of the last light pen interrupt
LPY	FFFF	1	the (Y coordinate/2) of the last light pen interrupt
LPSTAT	FFFD	1	0 if no light pen interrupt has occurred, 1 otherwise (you should reset to 0 to acknowledge a light pen interrupt)
HX	FFBF	2	the current X coordinate of the crosshair
HY	FFC1	2	the current Y coordinate of the crosshair
HSTAT	FFBE	1	1 if the crosshairs are visible, 0 otherwise (the DRAWHAIRS entry point does not maintain this cell - you should do it manually when calling DRAWHAIRS
ROMCHAR	09FA	-	the begining of the ROM character generator

Appendix 4

4K to 8K EPROM Addressing Modification

**** CAUTION : Only 3 voltage 2716's may be used on MicroAngelo ****

```
************************************************
** For maximum warranty coverage, boards should **
** be returned to factory for modification.     **
** Warranty void on boards damaged by improper  **
** modification in the field.                   **
************************************************
```

Note: This modification is for use of the 3 voltage 2716 EPROM's such as manufactured by Texas Instruments. (INTEL 2716's are not compatible.)

Steps:

1 Cut the trace between pins 1 and 2 of J9. Connect pins 2 and 3.

2 Cut the trace between pins 1 and 2 of J6 and cut the trace which connects pin 3 of J6 to ground. Connect pins 2 and 3 of J6 together.

3 Repeat step 2 for J7, J8, and J10.

3 Jumper pin 1 of J9 to pin 1 of J6, J7, J8, and J10.

After these modifications have been made 3 voltage 2716 EPROM's may be used in IC sockets U32 through U35. Note that the order in which the EPROM's are addressed after this modification is:

0000H - U32
0800H - U34
1000H - U33
1800H - U35